BRUSH

OPERATING INSTRUCTIONS

amplifier
model RD 5615 00

MP MASTER
MA30150

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■ Claim for damage in shipment

The instrument should be examined as soon as it is received. If it is damaged in any way, a claim should be filed with the carrier. A full report of the damage should be obtained from the claim agent, and this report should be forwarded to us. We will then advise you of the disposition to be made of the equipment and arrange for repair or replacement. Include model number, type number and serial number when referring to this instrument for any reason.

■ If any fault develops

1. Notify the nearest factory branch service station, address on the next page, giving full details of the difficulty, and include the model number, type number and serial number. Upon receipt of this information, we will give you service instructions or issue a material return authorization card.
2. You may request any necessary instrument packaging by telling us what cartons you need. These will be sent to you no charge.
3. Upon receipt of shipping instructions, forward the instrument prepaid, and repairs will be made at the factory. If requested, an estimate of the charges will be made before the work begins, provided the instrument is not covered by the warranty.

WARRANTY

Each instrument manufactured by Brush Instruments, Division of Clevite Corporation, is warranted to be free from defects in material and workmanship and to operate in accordance with the published specifications when used with the recommended Brush associate equipment and with Brush chart paper. Liability under this warranty is limited to servicing or adjusting any instrument returned to a factory branch service station for that purpose and to replacing any defective parts thereof except tubes, fuses, and batteries.

This warranty is effective for one year after delivery to the original purchaser. When the instrument is returned transportation charges are to be prepaid by the original purchaser. If defective operation has been caused by misuse or abnormal conditions of operation, repairs will be billed at our current rate. In this case an estimate will be submitted before work is started.

SUPPLIES AND SERVICE

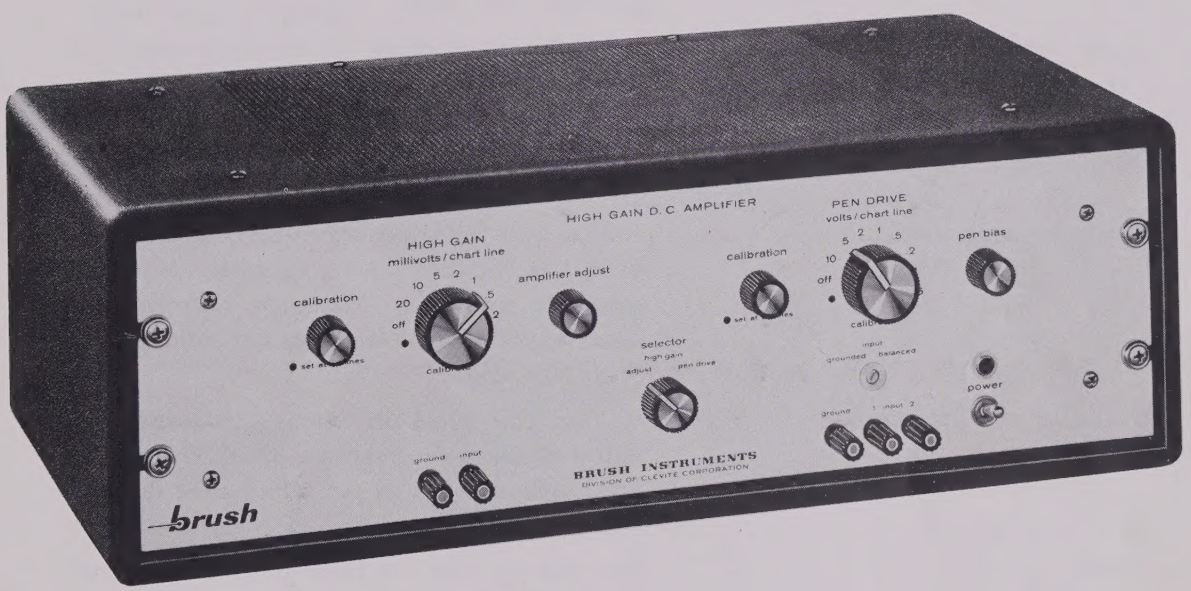
Brush Instruments factory branch offices and service stations:

CLEVELAND
Mid-West
3405 Perkins Avenue
Cleveland 14, Ohio
Phone: ENdicott 1-3315

ARLINGTON
East Coast
561 - 23rd St., South
Arlington 2, Virginia
Phone: OTis 4-5912

LOS ANGELES
West Coast
1960 So. La Cienega Blvd.
Los Angeles 34, California
Phone: TExas 0-7517

HIGH GAIN D. C. AMPLIFIER MODEL RD 5615 00



High Gain D.C. Amplifier Model RD 5615 00.

The High Gain D.C. Amplifier Model RD 5615 00 is both a high gain d.c. amplifier and a medium gain d.c. amplifier. The unit is designed for use in laboratory or field instrumentation systems, and specifically for use with a matching Brush oscillograph using Brush chart paper.

As a high gain direct coupled d.c. amplifier the unit provides low drift as a result of chopper stabilization of the high gain d.c. amplifier circuit. In such operation, the amplifier will accept single-ended signals in the range of 100 microvolts to 0.80 volts.

As a medium gain d.c. amplifier, the amplifier is capable, at maximum sensitivity, of deflecting a Brush oscillograph pen 1 mm with an amplifier input signal of 10 mv.

The High Gain D.C. Amplifier Model RD 5615 00 is designed for use with Brush "RD" series oscillographs. The unit may be used with earlier Brush oscillographs, but the frequency response of the amplifier must be adjusted for use with the penmotors in such oscillographs.

SPECIFICATIONS

Sensitivity with Brush oscillograph	100 microvolts per chart line (mm). Full scale deflection from chart center ±2.0 millivolts.
Sensitivity steps	.1, .2, .5, 1, 2, 5, 10, and 20 millivolts per chart line (mm), or .05, .1, .2, .5, 1, 2, 5 and 10 volts per chart line (mm).
Input impedance	1 megohm single-ended for sensitivity steps from .1 to 20 millivolts per chart line (mm). 5 megohms single-ended, or 10 megohms balanced for sensitivity steps from .05 to 10 volts per chart line (mm).
Common mode rejection	1000 to 1, at full sensitivity (.05 Volts/Chart Line setting) of balanced input connection. Maximum attenuator error 1%. Maximum common mode signal is 1000 times Volts/Chart Line switch setting up to 500 volts.
Amplifier zero line stability	½ chart line (mm) per hour, or less, when used with a Brush oscillograph and Brush chart paper. Total drift over 8 hour period not more than one chart line (mm).
Noise	Less than ½ chart line (mm) noise on chart with 1 megohm across shielded input.
Calibration	Signal derived from internal mercury cell.
Signal expander	A pen positioning control (PEN BIAS) is provided. This control permits balancing out the static component of a complex signal, deflecting the signal zero line as much as 200 lines (ten times full scale deflection) either side of chart center, except when balanced input is used.
Frequency response	Recorded peak to peak amplitude of a constant voltage sine wave will be within ±1 chart line (mm) of a nominal 10 lines from d.c. to 100 cps when the amplifier is compensated with a Brush oscillograph.
Output impedance	Approximately 50 ohms.
Maximum output current	±20 milliamperes into 1500 ohms.
Input power required	105 to 125 volts (or 95 to 115 volts), 55 to 65 cps, 90 watts at 115 volts, 60 cps.
Power cable	2 wire attached cord. 3 wire attached cord available on special order.

Tubes	6-12AT7, 2-12AX7, 1-12AY7, 2-5687, 1-6BW4, 1-6080, 1-5751, and 1-6626.
Dimensions	Standard panel: 19″ wide x 5¼″ high x ¼″ thick. Depth: 10¾″ (with connectors 12½″).
Net weight	22 pounds.
Shipping weight	28 pounds.
Signal input terminals	
Front	Binding posts.
Rear	3 pin male AN type for signals at .05 volts to 400 volts (matching connector supplied).
Output terminals	6 pin female AN type (cable to connect amplifier to Brush "RD" series oscillographs supplied).

Remove the amplifier and all accessory items from the carton. See that all items in the packing list (below) are included in the shipment. Examine the instrument and accessory items for damage. For procedure to be followed if damage is noted, refer to "Claim for Damage in Shipment" following the Table of Contents.

PACKING LIST

When the High Gain D.C. Amplifier Model RD 5615 00 is ordered as part of a matched recording system, only those items necessary for connection and use of the amplifier with other instruments in the system are included in the shipment.

The following items are included when the amplifier alone is purchased:

1. One amplifier-to-oscillograph signal cable, Part No. 223385-501 (Fits all Brush "RD" series Oscillographs).
2. One signal input connector (3 pin female, AN type), Part No. 121275.
3. One cable clamp (for 3 pin connector), Part No. 119993-104.
4. One connector, shielded plug, Part No. 119993-106.

INSTALLING THE INSTRUMENT IN RACK OR PORTABLE CASE

The High Gain D.C. Amplifier may be installed in a standard 19″ rack or in the Brush Portable Case Model RA 1105 30. For rack mounting, the amplifier may be mounted in the Brush RA 1152 60 Rack, which is designed to accommodate six 5¼″ high amplifiers and one RD 2662 00 series oscillograph. The rack includes a blower and duct for adequate ventilation of the system. If the Brush RA 1152 60 Rack is not used, ventilation must be provided for proper operation of the amplifier and associated equipment. Adequate ventilation is important to the proper operation of electronic equipment and components.

To install the amplifier in a standard 19″ rack, position the instrument in the rack, secure the front panel to the rack rails with four screws, and connect external cables at the front or rear of the amplifier as described below.

In applications where maximum portability is desired, the Brush Portable Case Model RA 1105 30 is recommended. The case, finished in grey wrinkle enamel, is 20⅛″ wide, 6⅜″ high, and 10⅜″ deep; it is designed to accommodate any of the Brush line of rack-mounted instruments built on the standard 19″ panel, 5¼″ high, and ¼″ thick. Although extremely rigid, the case is light in weight (8 pounds, 5 ounces). A recessed strap-type carrying handle increases its portability. A number of Portable Cases may be stacked vertically, affording some of the advantages of rack mounting without detracting from the portability of the individual amplifiers. The amplifier may be ordered with a 3 conductor power cable for portable applications.

When the Amplifier and Portable Case are purchased together, the Amplifier is installed in the case at the factory.

To install the Amplifier in the Brush Portable Case Model RA 1105 30, proceed as follows:

1. Remove both the top and bottom sections of the wrap-around cover of the instrument to be case mounted.
2. Stand the case on its back.
3. Place the four sheet spring nuts over the four holes in the recessed portion of the front of the case.
4. Slip the chassis into the case.
5. Lift one end of the case slightly to align the holes through the bottom with the corresponding threaded holes in the chassis. Start (but do not tighten) two pan head machine screws (#8-32 x 1″ long) at bottom rear of the case.
6. Mount the four rubber feet on four pan head machine screws (#8-32 x 1⅛″ long).
7. Start (but do not tighten) the screws with the rubber feet, first in one end of the bottom of the case, and then in the other.
8. Start (but do not tighten) six pan head machine screws (#8-32 x 1″ long) through the top of the case and into the amplifier chassis.
9. Insert and tighten the four oval head, cross recessed, self tapping type "A" screws, with countersunk trim washers and nylon grommets, through the front panel and into the case.
10. Tighten the screws previously started at the top and bottom of the case.

PREPARATION FOR USE

USE WITH OSCILLOGRAPHS

The Brush High Gain D.C. Amplifier is designed to be used with Brush "RD" series oscillographs. It may be used with Brush "BL" series oscillographs, but frequency response and sensitivity will differ from the values noted under "Specifications". The High Gain D.C. Amplifier must be grounded adequately, either to a grounded rack or a grounded conduit.

"RD" series amplifiers and oscillographs are frequency compensated at the factory when purchased together. If they are purchased separately, the amplifier frequency compensation may be adjusted as described below under "Frequency Compensation of the Medium Gain D.C. Amplifier Section".

CONNECTING AMPLIFIER TO OSCILLOGRAPH

The output terminals of this amplifier are 30 volts (d.c.) above chassis, and should not be connected to any load in which either terminal is grounded. To connect the amplifier to an oscillograph, proceed as follows:

1. See that the amplifier and oscillograph are disconnected from their power source, and that power switches of the amplifier and oscillograph are in "off" position.
2. Connect the amplifier OUTPUT connector (Fig. 1), on the back of the amplifier, to the oscillograph input connector with the cable supplied.

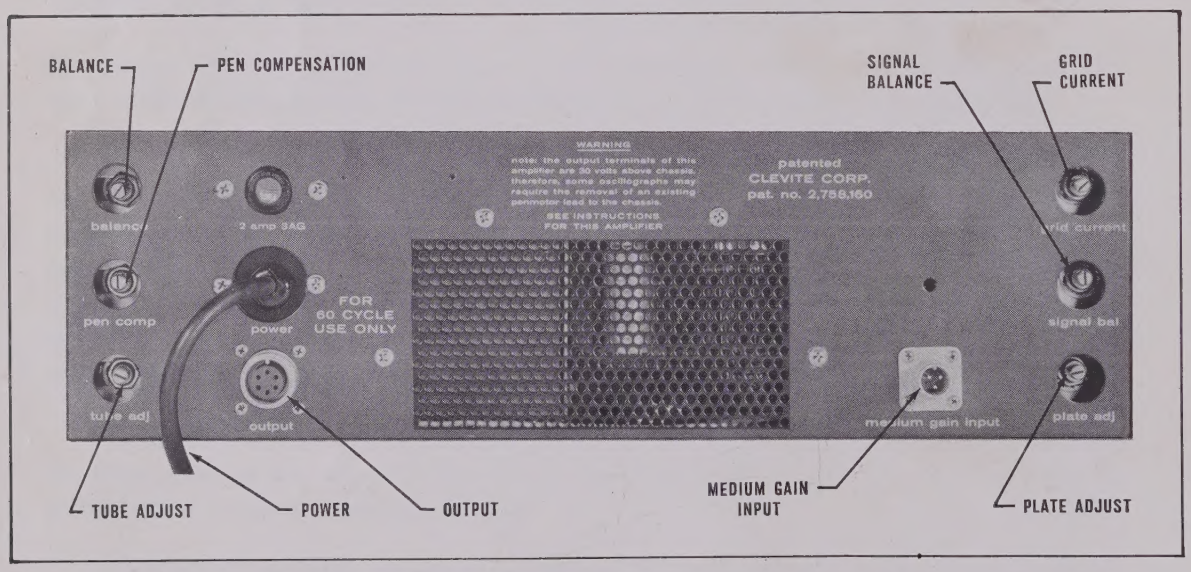


Fig. 1. Rear Panel—High Gain D.C. Amplifier Model RD 5615 00.

CONNECTING AMPLIFIER AND OSCILLOGRAPH TO POWER SOURCE

1. Refer to the operating instructions for the oscillograph. Connect the oscillograph to its power source, and test for proper operation. Turn the oscillograph power switch "off".
2. Connect the amplifier POWER cable (Fig. 1) to an appropriate power source. (Although the amplifier operates normally on a power line voltage of 105 to 125 volts, power transformer connections may be modified for operation at 95 to 115 volts. See "Modification of Power Transformer Connections for Operation at 95 to 115 Volts" in Section V—Maintenance.)

BALANCING AND FREQUENCY COMPENSATION

The medium gain d.c. amplifier section is balanced at the factory and, if the amplifier is purchased with an oscillograph, the amplifier is frequency compensated to that oscillograph. Balancing procedures described below are necessary only when new tubes are installed in the instrument, or when operation of the CALIBRATION control (Fig. 2) causes pen to shift. Frequency compensation procedures described below are necessary only when the amplifier is used with an oscillograph other than the one with which it was purchased. For routine operation, omit balancing and frequency compensation procedures and continue with "Operation as a High Gain D.C. Amplifier", below.

BALANCING THE MEDIUM GAIN D.C. AMPLIFIER SECTION

The medium gain d.c. amplifier section should be balanced after connection of the amplifier and oscillograph to their power source. To balance the medium gain d.c. amplifier section, proceed as follows:

1. Turn the SELECTOR switch (Fig. 2) to "pen drive". Turn the VOLTS/CHART LINE switch (Fig. 2) to "off". Turn the amplifier POWER switch (Fig. 2) to "on" and allow 15 minutes for the amplifier to warm up.
2. Turn the oscillograph "on" at slow chart speed (to conserve chart paper), and set the INPUT switch (Fig. 2) in the "balanced" position.
3. Turn the pen drive CALIBRATION control (Fig. 2) full clockwise, and bring the oscillograph pen approximately to chart center by means of the TUBE ADJUST control on the rear panel of the amplifier (Fig. 1).
4. Turn the BALANCE control, on the rear panel of the amplifier (Fig. 1), to its extreme counterclockwise position. Rapidly rotate the CALIBRATION control (Fig. 2) counterclockwise, then clockwise, while turning the BALANCE control slowly clockwise until no pen deflection is noted.
5. Center the pen on the chart by means of the TUBE ADJUST control on the rear panel of the amplifier (Fig. 1), and turn the oscillograph "off".

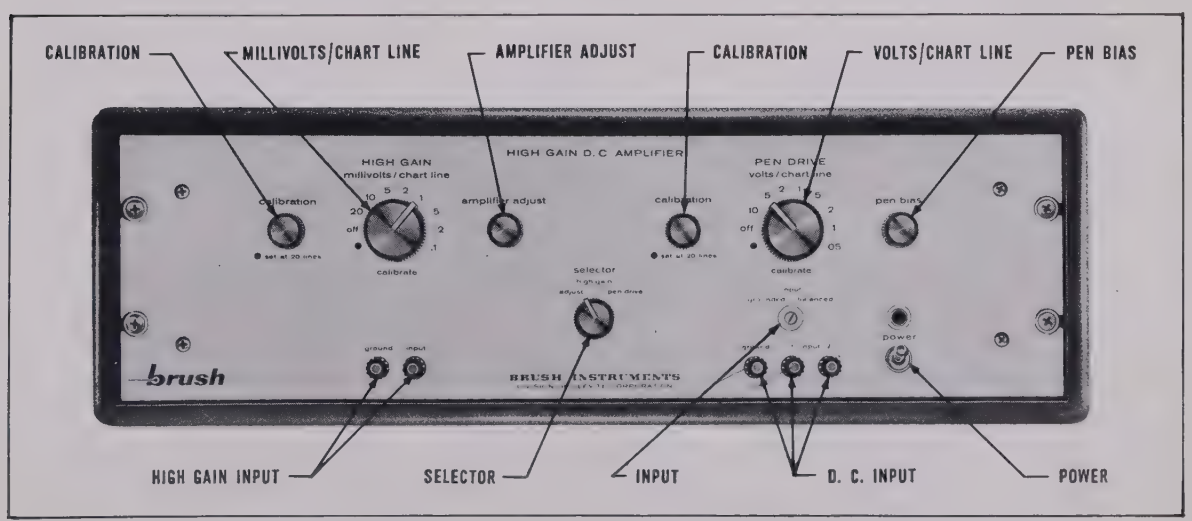


Fig. 2. Front Panel Controls and Connectors—High Gain D.C. Amplifier Model RD 5615 00.

FREQUENCY COMPENSATION OF THE MEDIUM GAIN D.C. AMPLIFIER SECTION

To obtain optimum frequency response of a Brush amplifier-oscillograph combination, the frequency response of the medium gain d.c. amplifier section must be adjusted to match the penmotor of the oscillograph. (When an amplifier and an oscillograph are purchased as a matched recording system, this adjustment is made at the factory. If the instruments are purchased separately and if frequencies over 30 cps are to be recorded, the frequency compensation procedure must be observed.) When the High Gain D.C. Amplifier is used with a Brush oscillograph and flat response to high frequencies is not required, pen compensation may be turned off by turning the inner shaft of the dual concentric PEN COMPENSATION control (Fig. 1) fully counterclockwise.

To match the medium gain d.c. amplifier section to an oscillograph, follow the procedures described under "Balancing the Medium Gain D.C. Amplifier Section", above, and proceed as follows:

1. Connect an oscillator covering the range from 10 to 100 cps to the INPUT 1 terminal (Fig. 2) and the INPUT 2 terminal (Fig. 2) on the right side of the amplifier front panel. If the corresponding MEDIUM GAIN INPUT connector on the rear panel (Fig. 1) is used, connect the oscillator to pin "A" (ground) and pin "C". To reduce hum pickup it is recommended that shielded leads be used.

2. Set the SELECTOR switch (Fig. 2) in the "pen drive" position.

3. Set the INPUT switch (Fig. 2) in the "grounded" position. When the INPUT switch is in the "grounded" position, the INPUT 1 terminal (Fig. 2) is shorted to ground, allowing connections to be made at the INPUT 1 and INPUT 2 terminals (Fig. 2).

4. Turn the oscillograph "on". Set the VOLTS/CHART LINE switch (Fig. 2) in the "10" position and, with the oscillograph operating at a chart paper speed of 20 or 25 mm/sec, center the oscillograph pen trace on the chart paper by means of the PEN BIAS control (Fig. 2).

5. Turn the inner shaft of the dual concentric PEN COMPENSATION control (Fig. 1) fully clockwise, and set the outer shaft of the dual concentric PEN COMPENSATION control (Fig. 1) in approximately mid-position.

6. Adjust oscillator output level at 10 cps for 10 lines total pen deflection (peak-to-peak). If oscillator output is not sufficient to produce 10 lines pen deflection, turn the VOLTS/CHART LINE switch (Fig. 2) to a more sensitive position until 10 lines pen deflection is noted. It may be necessary to increase or decrease the oscillator output voltage, or to change the setting of the pen drive CALIBRATION control (Fig. 2) to obtain the desired 10 line deflection. The oscillator output voltage is a reference voltage and must be held constant during the frequency compensation procedure; the settings of the oscillator output voltage control, the VOLTS/CHART LINE switch (Fig. 2), and the pen drive CALIBRATION control (Fig. 2) must remain unchanged.

7. At 100 cps (with oscillator output voltage the same as in step 6, above), adjust the outer shaft of the PEN COMPENSATION control (Fig. 1) as necessary to obtain a pen deflection of 10 chart lines.

8. Sweep the frequency range from 10 cps to 100 cps (holding oscillator output voltage constant) and check for flatness of response. Adjust the outer shaft of the dual concentric PEN COMPENSATION control (Fig. 1), if necessary, to obtain optimum response from 10 cps to 100 cps. Turn the oscillograph "off".

OPERATION AS A HIGH GAIN D. C. AMPLIFIER

The Brush High Gain D.C. Amplifier Model RD 5615 00, when used as a high gain d.c. amplifier, can be used with signal input voltages up to 0.4 volt (single-ended only).

CONNECTION OF INPUT SIGNALS TO THE HIGH GAIN D.C. AMPLIFIER SECTION

Because of the extremely high gain of this amplifier, certain precautions must be taken in connecting signals to the high gain INPUT terminals to prevent the introduction of spurious signals in the recording being made. The same care must be exercised during the balancing and calibration of the high gain d.c. amplifier section.

The high gain section will accept only single ended input signals. In general, all input signals derived from signal sources with an internal impedance of 1000 ohms or higher should be connected to the High Gain D.C. Amplifier through shielded cable and a shielded GR type connector. The ground of the shielded connector must be connected to the GROUND terminal on the amplifier front panel. Input signals from signal sources with very low internal impedance, such as thermocouples, may be connected to the High Gain D.C. Amplifier without shielding.

During the balancing and calibration procedures, the high gain input terminals must be shielded with the open, shielded, GR type connector supplied with the High Gain D.C. Amplifier.

The amplifier may be used with equipment other than the oscillograph when extended frequency response is desired. Amplifier output is taken from pins "B" and "C" of the OUTPUT connector on the rear panel (Fig. 1), and the inner shaft of the dual concentric PEN COMPENSATION control is turned counterclockwise until the switch is actuated.

BALANCING THE HIGH GAIN D.C. AMPLIFIER SECTION

Before the unit is used for high gain operation, the high gain d.c. amplifier section must be balanced, as follows:

1. With the amplifier connected to an oscillograph, and with the amplifier and oscillograph connected to a suitable power source, turn the SELECTOR switch (Fig. 2) to the "high gain" position.

2. Turn the POWER switch (Fig. 2) "on", and allow 15 minutes for the amplifier to warm up.
3. Place an open shielded GR type connector (supplied with the amplifier) over the high gain GROUND and INPUT terminals (Fig. 2), being careful to match the "G" of the connector with the GROUND terminal.
4. Turn the MILLIVOLTS/CHART LINE switch (Fig. 2) to "off" position and, with the oscillograph running at slow chart speed, bring the pen to chart center by means of the PEN BIAS control (Fig. 2).
5. Turn the MILLIVOLTS/CHART LINE switch (Fig. 2) to its extreme *clockwise* position (".1").

The MILLIVOLTS/CHART switch must remain in the ".1" position during the balancing procedure.

6. Turn the SELECTOR switch (Fig. 2) to the "adjust" position and bring the oscillograph pen *approximately* to chart center by means of the AMPLIFIER ADJUST control (Fig. 2). When the SELECTOR switch is in the "adjust" position, the correction circuit in the high gain section of the amplifier is disconnected. For this reason the inherent drift of the amplifier will be indicated on the oscillograph chart. The function of the AMPLIFIER ADJUST control is to adjust the amplifier only to an approximately balanced condition, so that only a small error must be corrected by the amplifier.
7. Set the SELECTOR switch (Fig. 2) in the "high gain" position. Turn the MILLIVOLTS/CHART LINE switch (Fig. 2) to "off" position and check the pen trace in relation to the center line of the chart paper. Re-adjust the pen to chart center, if necessary, by means of the PEN BIAS control (Fig. 2).

Because of the high sensitivity of the amplifier when the SELECTOR switch is in the "high gain" position, the unit must be protected from all stray noise pickup.

CALIBRATING THE HIGH GAIN D.C. AMPLIFIER SECTION

With the amplifier balanced as described above, and with the oscillograph operating at slow chart speed, disconnect signal cables from the high gain INPUT and GROUND terminals (Fig. 2). Install the open, shielded GR type connector (supplied) on the high gain INPUT and GROUND terminals (Fig. 2), and calibrate the amplifier as described below:

1. Turn the MILLIVOLTS/CHART LINE switch (Fig. 2) to the "calibrate" position and adjust the high gain CALIBRATION control (Fig. 2) as necessary for a pen deflection of 20 chart lines.

2. Turn the MILLIVOLTS/CHART LINE switch (Fig. 2) to the ".1" position (with no input applied to the amplifier). If the pen trace does not return to chart center, but is *less* than 1 chart line from chart center, bring the pen to chart center by means of the PEN BIAS control (Fig. 2). If the pen trace is *more* than 1 chart line from chart center, bring the pen to the center of the chart by means of the GRID CURRENT control on the rear panel of the amplifier (Fig. 1).
3. Turn the MILLIVOLTS/CHART LINE switch (Fig. 2) to off.

It is absolutely necessary that the MILLIVOLTS/CHART LINE switch be turned "off" before an input is applied to the high gain section of the amplifier.

NORMAL OPERATION OF THE HIGH GAIN D.C. AMPLIFIER SECTION

1. Remove the open shielded GR type connector previously placed across the GROUND and INPUT terminals (Fig. 2).
2. Connect the signal to be recorded at the GROUND and INPUT terminals (Fig. 2) by means of a *shielded GR type connector.*
3. Advance the MILLIVOLTS/CHART LINE switch (Fig. 2) in a *clockwise* direction ("20", "10", etc.) to the desired operating position. The signal voltage is equal to the number of chart lines of pen deflection from the zero reference position, multiplied by the setting of the MILLIVOLTS/CHART LINE switch.

OFF-CENTER ZERO OPERATION OF THE HIGH GAIN D.C. AMPLIFIER SECTION

When the amplifier is used in high gain operation, the zero reference position of the oscillograph pen may be moved from the chart line to any arbitrary position on the chart paper by means of the PEN BIAS control (Fig. 2). Such an arbitrary position then becomes the zero reference line.

The maximum off-center zero range possible with the high gain d.c. amplifier section for each setting of the MILLIVOLTS/CHART LINE switch (Fig. 2) is as follows:

MILLIVOLTS/CHART LINE SWITCH SETTING	MAXIMUM ZERO REFERENCE LINE DISPLACEMENT
20	50 chart lines (mm)
10	50 chart lines (mm)
5	50 chart lines (mm)
2	50 chart lines (mm)
1	50 chart lines (mm)
.5	100 chart lines (mm)
.2	200 chart lines (mm)
.1	200 chart lines (mm)

OPERATION AS A MEDIUM GAIN D. C. AMPLIFIER

The Brush High Gain D.C. Amplifier Model RD 5615 00, when used as a medium gain d.c. amplifier, can be used with signal input voltages from 50 millivolts to 400 volts. As a medium gain d.c. amplifier, the unit will accept either single-ended or balanced input signals. In such application, the high gain d.c. amplifier section remains idle.

SINGLE-ENDED AND BALANCED INPUT SIGNALS APPLIED TO THE MEDIUM GAIN D.C. AMPLIFIER SECTION

The medium gain d.c. amplifier section of the High Gain D.C. Amplifier will accept either single-ended or "balanced" input signals. A single-ended signal is obtained from a circuit having one terminal already at ground potential, or a circuit which will not be disturbed if one terminal is connected to ground or to the amplifier chassis.

A "balanced" or double-ended signal, as used in connection with the medium gain d.c. amplifier section, is a signal obtained from a circuit which will be disturbed when one terminal is connected to ground. For example, the voltage across the secondary winding of a transformer with an intermediate tap connected to ground may be defined as a "balanced", or double-ended signal. Grounding of either output terminal of such a circuit would short circuit the transformer.

CALIBRATION OF THE MEDIUM GAIN D.C. AMPLIFIER SECTION

After matching the medium gain d.c. amplifier section with its penmotor (see "Frequency Compensation of the Medium Gain D.C. Amplifier Section", above), calibrate the d.c. amplifier section, following the procedures described below.

1. Turn the SELECTOR switch (Fig. 2) to the "pen drive" position, and turn the INPUT switch (Fig. 2) to the "balanced" position. If the oscillograph pen trace is not on the center line of the chart paper, repeat the procedures described under "Balancing the Medium Gain D.C. Amplifier Section", above.

2. Turn the VOLTS/CHART LINE switch (Fig. 2) to the "calibrate" position, and adjust the pen drive CALIBRATION control (Fig. 2) as necessary to produce a pen deflection of 20 chart lines. Turn the VOLTS/CHART LINE switch to "off".

   Check 20 line deflection by again turning the VOLTS/CHART LINE switch (Fig. 2) to the "calibrate" position. If necessary, readjust the pen drive CALIBRATION control (Fig. 2) to obtain a pen deflection of 20 chart lines.

PRELIMINARY OPERATION OF THE MEDIUM GAIN D.C. AMPLIFIER SECTION

Connect the medium gain d.c. amplifier section to a signal source of a known amplitude by means of the GROUND, INPUT 1, and INPUT 2 terminals (Fig. 2) on the right side of the front panel, or by means of the MEDIUM GAIN INPUT connector on the rear panel (Fig. 1), using shielded leads when the impedance of the signal source is high.

When connecting a single-ended input at the front panel, connect the "hot" side (in reference to ground) to the INPUT 2 terminal (Fig. 2). Connect the side of the signal to be grounded to the GROUND terminal (Fig. 2) or the INPUT 1 terminal (Fig. 2).

When connecting a single-ended input at the rear panel, connect the "hot" side of the signal to pin "C" of the MEDIUM GAIN INPUT connector (Fig. 1), and connect the side of the signal to be grounded to pin "B" or pin "A". When the INPUT switch (Fig. 2) is in the "grounded" position, pin "B" is shorted to pin "A", so that either pin may be used as a ground connection.

To connect a balanced input at the front panel, connect one side of the input circuit to the INPUT 1 terminal (Fig. 2), and the other side to the INPUT 2 terminal (Fig. 2), on the right side of the front panel.

To connect a balanced input at the rear panel, connect one side of the input circuit to pin "B" of the MEDIUM GAIN INPUT connector (Fig. 1), and the other side to pin "C". The ground point of the signal source, if available, as well as signal cable shielding, should be connected to the GROUND terminal on the front panel, or to pin "A" of the MEDIUM GAIN INPUT connector on the rear panel.

NORMAL OPERATION OF THE MEDIUM GAIN D.C. AMPLIFIER SECTION

1. Turn the VOLTS/CHART LINE switch (Fig. 2) successively to "10", "5", etc., to reach the desired sensitivity. The signal voltage is equal to the number of lines of pen deflection, from the signal zero position, multiplied by the setting of the VOLTS/CHART LINE switch.

2. Adjust the oscillograph pen to the desired position on the chart paper by means of the PEN BIAS control (Fig. 2) if the INPUT switch (Fig. 2) is in the "grounded" position. No adjustment can be made if the INPUT switch is in the "balanced" position. See "Calibration of the Medium Gain D.C. Amplifier Section", above.

OFF-CENTER ZERO OPERATION OF THE MEDIUM GAIN D.C. AMPLIFIER SECTION

(When using single-ended input only)

It is often desirable to expand the recording of a small dynamic signal superimposed on a larger d.c. voltage for close examination. In such cases, the PEN BIAS control (Fig. 2) may be used, in conjunction with the VOLTS/CHART LINE switch (Fig. 2) for electrical displacement of the pen zero reference position as much as 200 lines either side of chart center. (Such signal expansion is possible only when a single-ended input is used.)

To expand the dynamic portion of a complex signal for more convenient study, proceed as follows:

1. Set the SELECTOR switch (Fig. 2) in the "pen drive" position, and set the INPUT switch (Fig. 2) in the "grounded" position.
2. Calibrate the recording system as described under "Calibration of the Medium Gain D.C. Amplifier Section", above. The pen drive CALIBRATION, or gain control (Fig. 2), once set, should not be moved during the study of the dynamic signal.
3. With the VOLTS/CHART LINE switch (Fig. 2) in the "10" position, center the oscillograph pen on the chart paper by means of the PEN BIAS control (Fig. 2).
4. Turn the VOLTS/CHART LINE switch (Fig. 2) to "5", "2", etc., until a satisfactory pen deflection is noted.
5. Note the number of lines of pen deflection representing the static component of the complex signal, where

   VOLTS/CHART LINE SWITCH SETTING × AVERAGE PEN DEFLECTION = STATIC COMPONENT OF SIGNAL VOLTAGE.

6. Using the PEN BIAS control (Fig. 2), move the recording of the dynamic signal across chart center to the opposite edge of the chart.
7. Repeat steps 4 and 6, above, until the recording of the dynamic signal can no longer be moved across chart center by operation of the PEN BIAS control (Fig. 2). Maximum accuracy of recording will be obtained when the dynamic signal is centered on the chart.
8. The amplitude of the dynamic component can then be determined by the formula

   VOLTS/CHART LINE SWITCH SETTING × DYNAMIC PEN DEFLECTION = DYNAMIC COMPONENT OF SIGNAL VOLTAGE.

The High Gain D.C. Amplifier Model RD 5615 00 includes a high gain preamplifier section consisting of an input circuit, a high gain d.c. amplifier circuit, an a.c. correction amplifier circuit, and an output circuit; a medium gain d.c. amplifier section consisting of an input circuit for separate use as a pen drive amplifier, a d.c. amplifier circuit, and an output circuit; an electronically-regulated power supply providing voltage for the plate and filament circuits. See Figure 3.

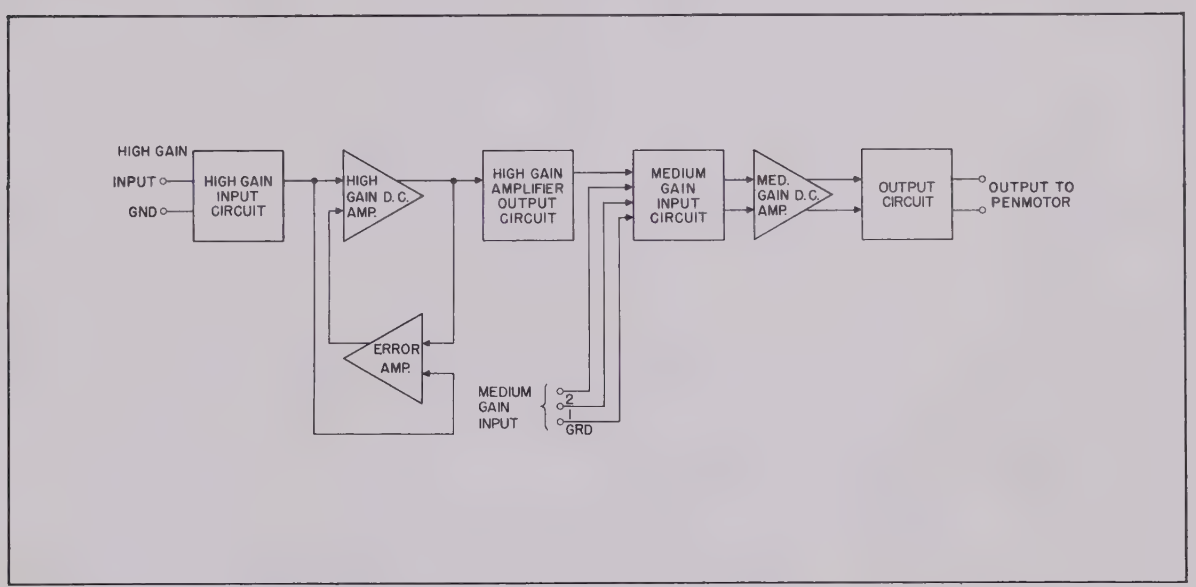


Fig. 3. Block Diagram—High Gain D.C. Amplifier Model RD 5615 00.

HIGH GAIN D. C. AMPLIFIER SECTION

INPUT CIRCUIT

A signal input from zero (0) to 400 millivolts is applied from the high gain input terminals to the millivolts/chart line attenuator (Fig. 4). This attenuator, with a constant impedance of 1 megohm, provides appropriate attenuation of the input signal. (Attenuation is provided in the input circuit for all but the four most sensitive positions of the millivolts/chart line switch. In the four most sensitive positions of the switch signals are first amplified, then attenuated in the output circuit.) The attenuated signal is applied to the calibration potentiometer (R-12), which provides continuous gain control from zero to full gain.

The amplifier is calibrated by means of a 2 millivolt signal derived from the mercury cell (B-1) and applied across the calibration potentiometer (R-12). Gain is adjusted to the desired level (normally 20 mm deflection on an oscillograph chart) by means of the calibration potentiometer.

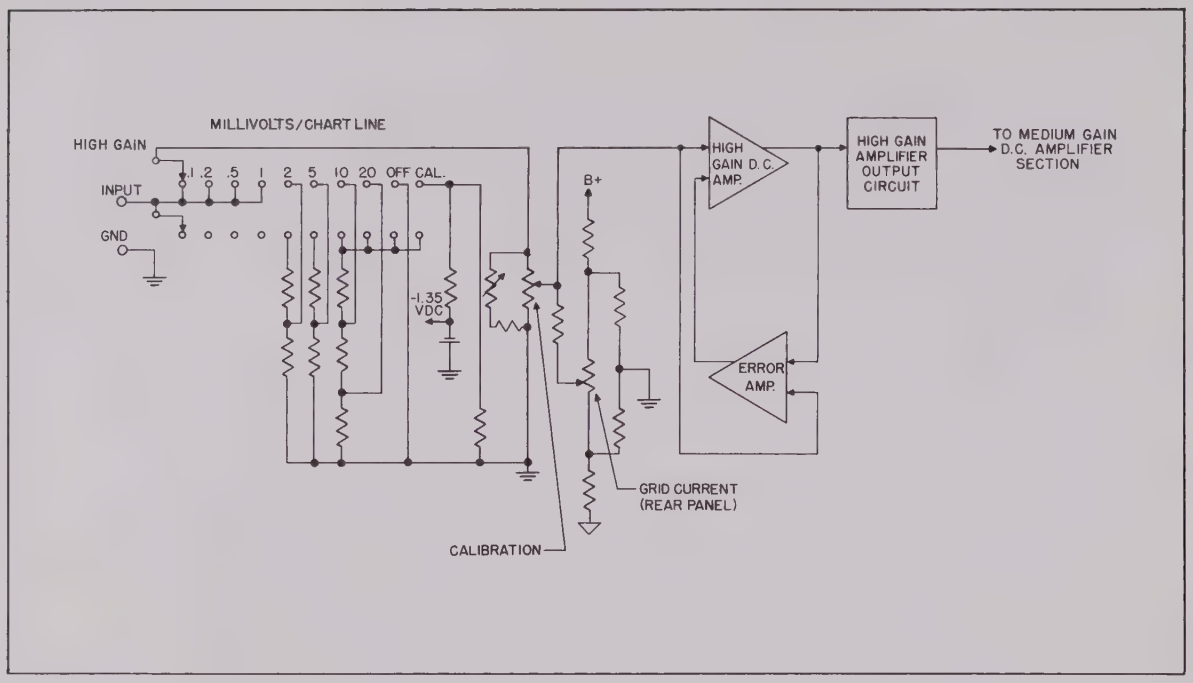


Fig. 4. Preamplifier Input Circuit.

HIGH GAIN D.C. AMPLIFIER CIRCUIT

The signal applied from the calibration potentiometer to the grid (pin 2) of the 12AY7 tube (V-1) is also applied to the correction summing point through the resistor R-19 (Fig. 5). A signal derived from the grid current adjust control (R-15) is also applied to the grid (pin 2) of the 12AY7 tube (V-1). This voltage compensates for the normal grid current in the input stage of the high gain d.c. amplifier section.

The signal applied to the grid (pin 2) of the 12AY7 tube (V-1) is coupled to the cathode (pin 8) in the second section of V-1, providing a differential signal between the plates (pins 1 and 6) of V-1. This differential signal is a resistance-coupled to three successive 12AT7 tubes (V-2, V-3, V-4), used as a conventional differential d.c. amplifier. The amplifier adjust control (R-30) and the cathode circuit of V-2 provide inherent balance within the d.c. amplifier section. Positive feedback is provided from the plate circuits of V-4 to the plate circuits of V-2, increasing the open loop gain of the d.c. amplifier section. In turn, this permits heavier negative feedback to be applied across the entire amplifier circuit (from the plates of V-4 to the cathodes of V-1) to provide gain stability in the amplifier.

Output of the high gain d.c. amplifier section is taken from one plate (Pin 6) of V-4. At this point the quiescent d.c. level of the circuit has been adjusted to match the d.c. signal input level at the grid (Pin 2) of V-1, by means of the plate adjust control (R-43). The signal voltage appearing at the plate (Pin 6) of V-4 is opposite in polarity to the input voltage; amplitude of the signal voltage is equal to the product of input voltage and the closed loop gain of the d.c. amplifier section, which is approximately 500.

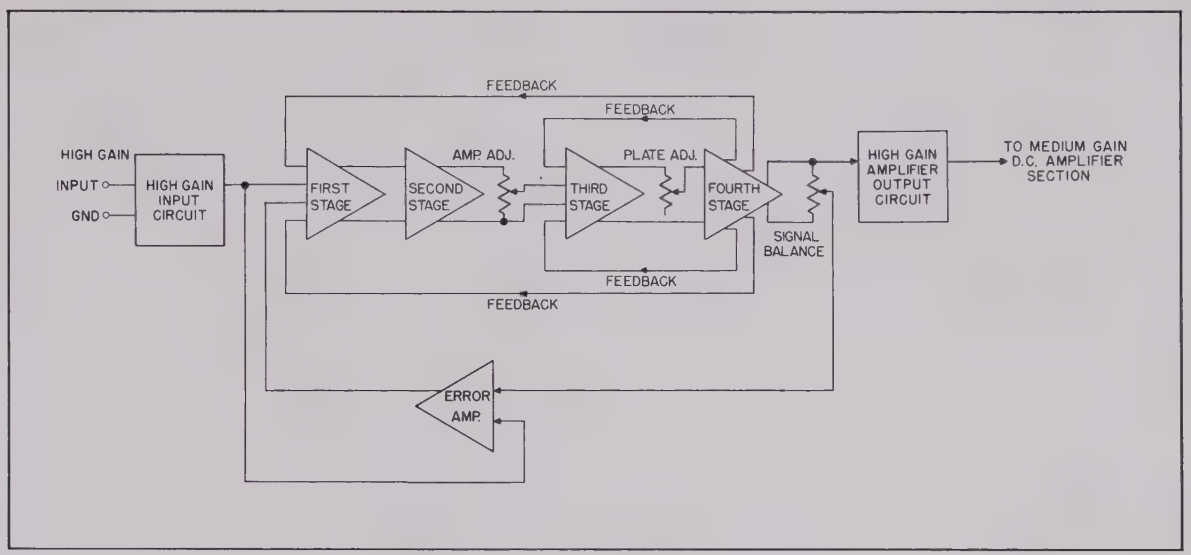


Fig. 5. High Gain D.C. Amplifier Circuit.

The output voltage appearing at pin 6 of V-4 is coupled to the associated pen drive amplifier section as well as to a voltage divider (R-54 and R-53). Division of voltage across R-54 and R-53 is such that voltage on the arm of the potentiometer R-53 is equal in magnitude but opposite in sign to amplifier input voltage at the grid (pin 2) of V-1. This voltage from the arm of R-53 is coupled to the correction summing point through the resistor R-60.

CORRECTION AMPLIFIER CIRCUIT

Input to the d.c. amplifier circuit is also coupled to a summing point in the a.c. correction amplifier circuit; output from the d.c. amplifier circuit is connected to this same summing point through the voltage divider R-19 and R-60 (Fig. 6). The two voltages appearing at the summing point are opposite in sign and equal in magnitude, unless a drift condition exists in the d.c. amplifier circuit. In this case, an error voltage directly proportional to the drift will be present at the summing point. This error voltage is converted to a correction signal in the error amplifier circuit and applied to the input of the d.c. amplifier circuit for reduction of drift in the high gain preamplifier section.

The error voltage is converted to a 60 cps square wave by a chopper (CH-1), and coupled through a capacitor (C-3) to the correction amplifier (Fig. 8). The correction amplifier, consisting of a 12AX7 tube (V-5) and a 12AT7 tube (V-6), is a conventional 4-stage a.c. amplifier, with a gain of approximately 20,000. Output of the correction amplifier is taken from the plate (pin 6) of V-6 and coupled through a capacitor (C-11) and a resistor (R-79) to the chopper (CH-1) for half-wave rectification. The resulting rectified signal is filtered by a resistor (R-80) and a capacitor (C-12), then coupled to the grid (pin 5) of the 12AY7 tube (V-1) in the high gain d.c. amplifier section. This signal, which is directly proportional to the drift in the d.c. preamplifier section, provides drift reduction by a factor of approximately 1000.

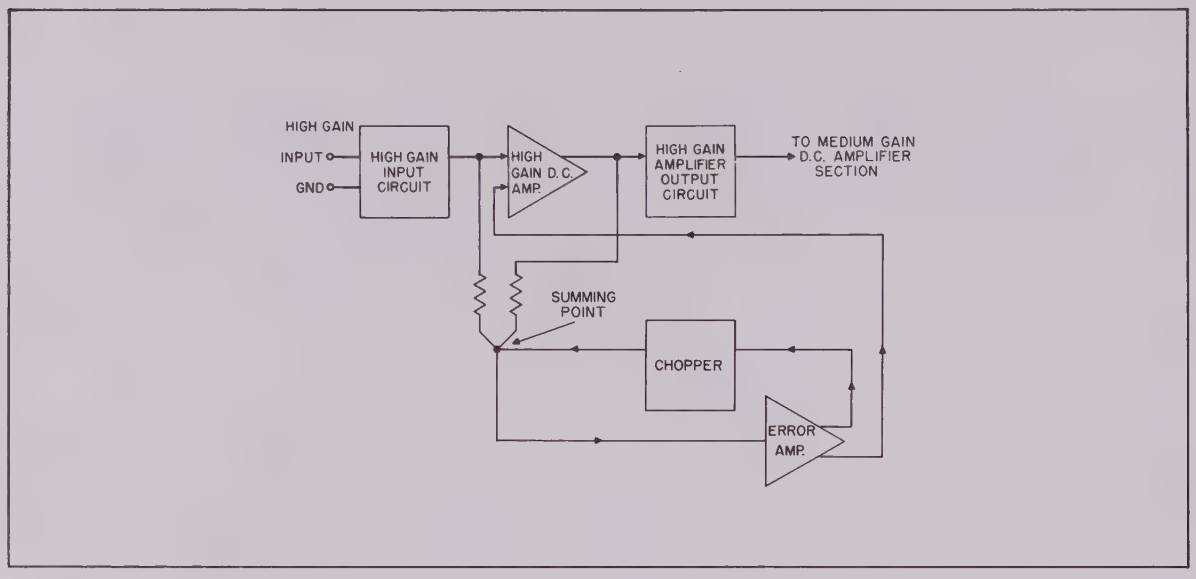


Fig. 6. Error Amplifier Circuit.

OUTPUT CIRCUIT

In the four most sensitive positions of the millivolts/chart line switch, voltages are attenuated *after* amplification in the output circuit (Fig. 7). In addition to use as an attenuator, the preamplifier output circuit carries preamplifier output to the medium gain d.c. amplier section.

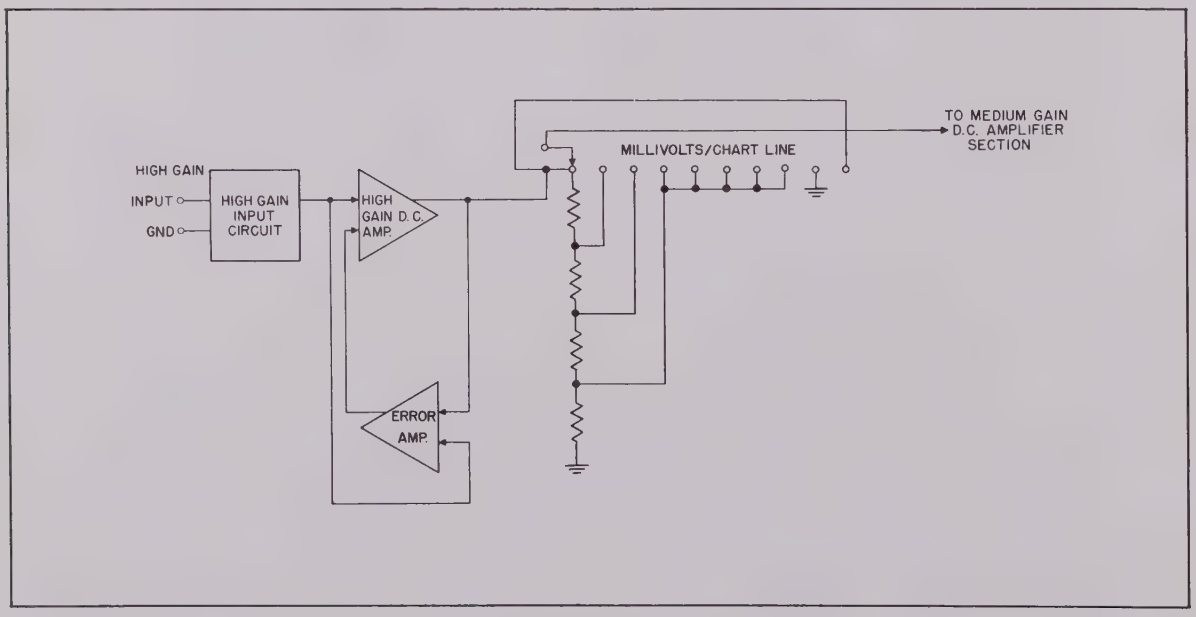


Fig. 7. Preamplifier Output Circuit.

MEDIUM GAIN D. C. AMPLIFIER SECTION

The medium gain d.c. amplifier section includes an input circuit, a d.c. amplifier circuit and an output circuit. The medium gain d.c. amplifier section amplifies the output of the high gain preamplifier section to the level required for driving a Brush oscillograph penmotor. If desired, the medium gain d.c. amplifier section may be used independently as a pen drive amplifier. A separate input circuit, provided for such operation, permits selection of single-ended or balanced input signals, attenuates signal voltages, and connects calibration or pen bias voltages to the pen drive section.

INPUT CIRCUIT

The constant resistance attenuator in the input circuit (Fig. 8) provides the means of varying the input level to the first stage of the amplifier circuit. This attenuator always presents 5 megohms resistance to a single-ended signal source, or 10 megohms resistance to a balanced signal source throughout the attenuator range. At the first position of the VOLTS/CHART LINE switch (.05 volt per millimeter) the input signal is not attenuated, and the sensitivity of the amplifier circuit is the same as during calibration.

For single-ended ("grounded") operation, input signals are coupled to the amplifier between the INPUT 2 terminal and the GROUND or INPUT 1 terminal. In this case, half of the attenuator is used to couple signals to one grid of the 12AX7 input tube (V-7). A pen bias signal, ~~derived from a mercury cell,~~ is coupled to the other grid of the input tube for positioning the oscillograph pen on the chart, or for providing pen zero displacement. For balanced operation, the dual attenuator couples input signals (connected between INPUT 1 and INPUT 2 terminals) to the grids of the input tube (V-7).

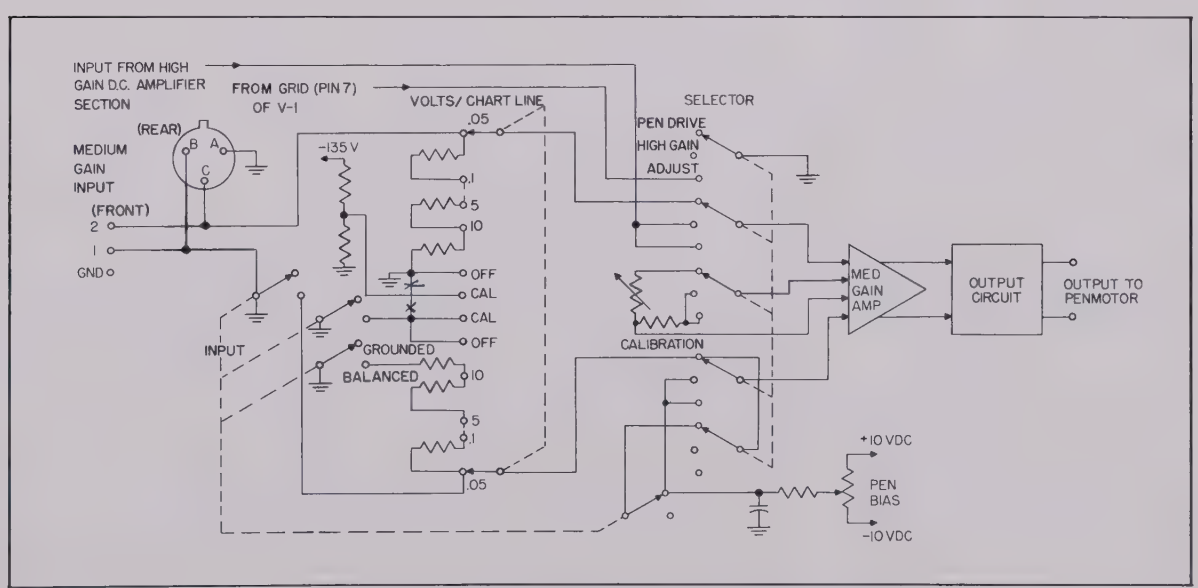


Fig. 8. Input Circuit—Medium Gain D.C. Amplifier Section.

D.C. AMPLIFIER CIRCUIT

The input stage of the pen drive amplifier circuit (Fig. 9) consists of a high gain dual triode (V-7) used as a differential d.c. amplifier. The input signal applied to this stage may include an inphase component and a differential component. The inphase component, applied to both input grids of V-7 at the same amplitude and polarity, is an unwanted signal.

Since the input circuit operates as two parallel amplifiers with high cathode degeneration, gain of the inphase component is effectively reduced in the input stage. The desired differential component of the input signal is applied between the two input grids of V-7 with opposite polarities. Since the signal currents flowing through the common cathode resistor are of opposite polarities, no degeneration occurs at that point. As a result, differential voltage gain is not reduced in the first stage.

Gain is controlled by the relatively small "uncommon" cathode degeneration resistance. Variation of this resistance with the gain potentiometer varies degeneration, and thus controls gain of the input stage. If the two tube halves of the input stage are not perfectly balanced, variation of the gain control will produce, in effect, a differential input signal, which is undesirable. Such an effect is eliminated by the "balance" potentiometer adjustment, which provides compensation for tube unbalance. At the plate circuits of the input stage, output voltages are summed with feedback voltages from the amplifier output circuit, and coupled to succeeding amplifier stages.

The second and third stages of the pen drive amplifier channel consist of two high gain dual triodes (V-8, V-9) used as conventional direct-coupled differential amplifiers. A balance control is provided in the second stage, to permit further compensation for tube unbalance in the last three stages of the amplifier circuit.

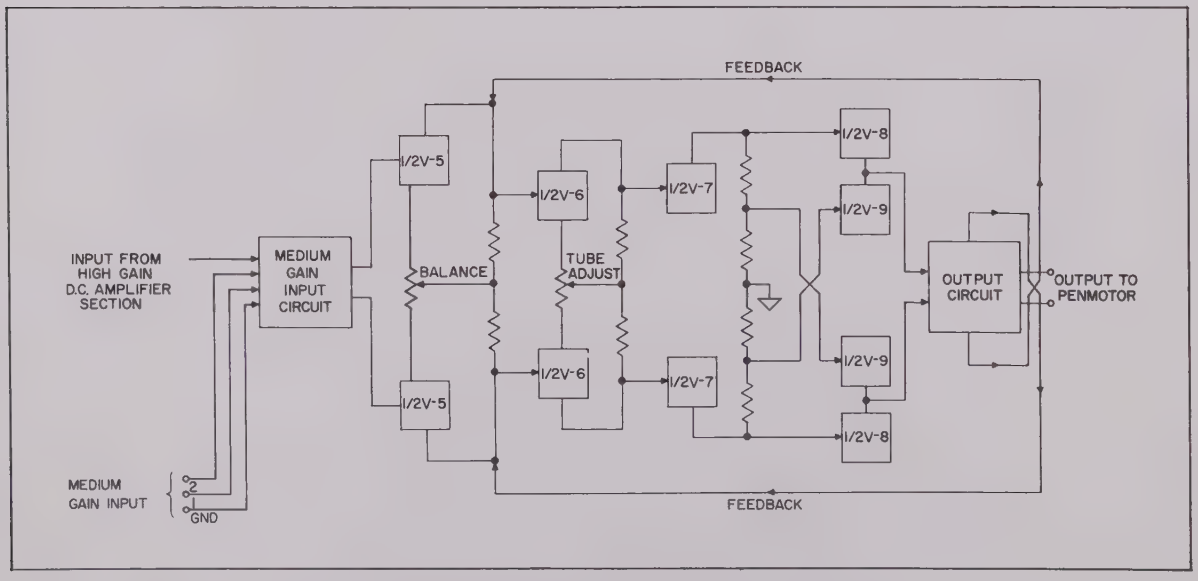


Fig. 9. Medium Gain D.C. Amplifier Circuit.

The third stage tube (V-9) is coupled to a pair of medium gain dual triodes (V-10, V-11), which operate as a bridge output circuit. The sections of each output tube appear at opposite arms of the bridge, so that the penmotor coil is, in effect, the load across the bridge. The signals which appear at the input grids of the bridge circuit are equal in amplitude, but opposite in polarity. A voltage divider applies a portion of each bridge input signal to one tube section. This tube section and the tube section receiving the full input signal are on opposite arms of the bridge circuit. (For example, if the full bridge input signal is applied to a grid of V-10, a portion of this same signal is applied to a grid of V-11, on the opposite arm of the bridge circuit.) Application of input voltages to the bridge circuit provides a low impedance series current path through the two tube sections to which positive voltages are applied, and through the penmotor. This causes deflection of the oscillograph pen. Reversing polarity of the input voltages produces a current path through the other two tube sections and through the penmotor. Because the direction of current flow through the penmotor coil has been reversed by the change in polarity of the input signals, the pen is now deflected in the opposite direction.

OUTPUT CIRCUIT

The output circuit of the medium gain d.c. amplifier section carries amplified signals to the oscillograph, and applies negative feedback to stabilize overall gain in the d.c. amplifier section. Negative feedback paths from the output terminals of the bridge circuit to the summing points in the plate circuits of the input tube (V-7) provide approximately 26 db of d.c. feedback (Fig. 10). The a.c. negative feedback around these paths may be reduced with increasing frequency by the complex filter in the feedback networks. The parallel "T" is designed to provide maximum attenuation in the frequency range of approximately 90 to 100 cps. Compensation of the frequency response of the amplifier to match that of the

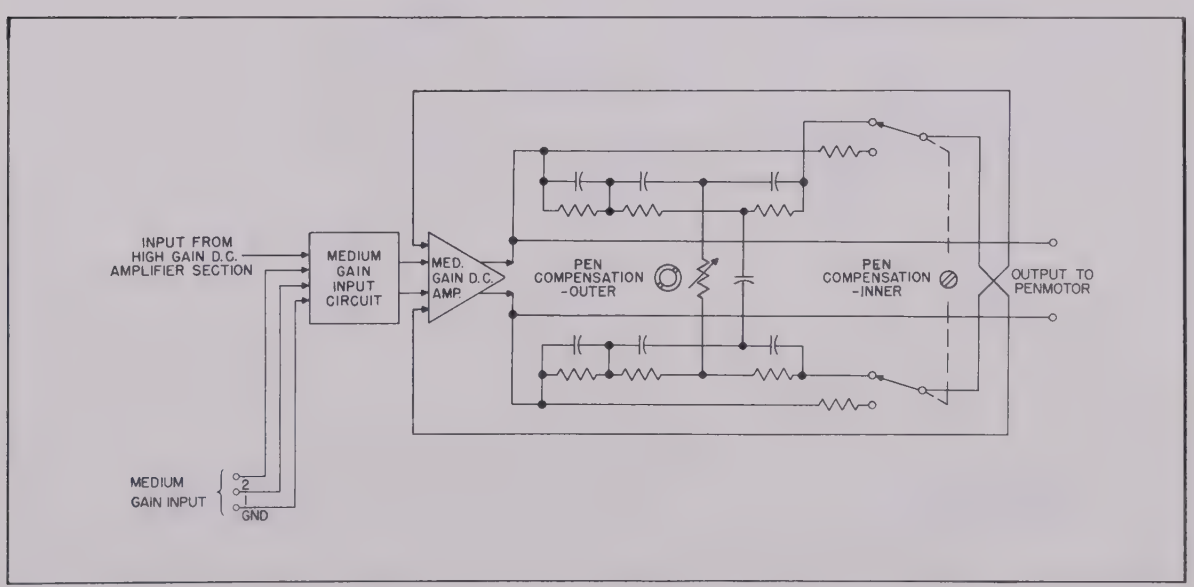


Fig. 10. Output Circuit—Medium Gain D.C. Amplifier Section.

penmotor is accomplished by varying the effect of this network through the use of a potentiometer across the parallel "T". This potentiometer varies the frequency of maximum attenuation in the filter. A switch is provided on the potentiometer for disconnecting the complex filter and replacing it with a fixed resistor in each feedback leg.

POWER SUPPLY SECTION

An electronically-regulated power supply with a wide frequency range is used in the High Gain D.C. Amplifier Model RD 5615 00, permitting operation from power lines in the frequency range of from 50 to 2000 cps. The power supply provides series-type regulation for plate voltage, and also provides filament voltage. High voltage from the transformer (T-1) is rectified in a 6BW4 tube (V-12) and applied to the plates of the 6080 series regulator tube (V-13). (The load is connected to the cathodes of the series regulator tube.) This output voltage is compared at the grid (Pin 7) of the 5751 tube (V-14) with voltage from a 6626 reference tube (V-15). This comparison determines whether or not the output voltage of the +B supply agrees with the desired voltage, as preset on the potentiometer (R-155). If not, a voltage change proportional to the error appears at the plate (Pin 6) of the 5751 tube. This voltage is amplified by the other section of the 5751 tube and applied as a bias voltage to the 6080 series regulator tube. This correcting action is continuous, regulating the output voltage of the power supply for varying conditions of load and input voltage.

The +B output of the power supply is connected to the —B output by a voltage divider (R-162, R-163, R-164, and R-165), which establishes the potential from —B to chassis ground for operation of the double-ended amplifier system (high gain preamplifier and medium gain d.c. amplifier sections). This voltage divider also provides pen bias voltage used for positioning the oscillograph pen. Filament voltages for the amplifier system are derived from transformers T-1 and T-2. A selenium rectifier (SR-1) rectifies transformer output, providing d.c. filament voltage for all tubes in the high gain preamplifier section (V-1 through V-6). All other tubes in the amplifier receive a.c. filament voltage directly from the transformers. An intereference filter, located at the power input of the power supply, minimizes the effect of any transients present in the power line.

This amplifier has been balanced and adjusted accurately before shipment from the factory, and should give long, trouble-free service. For any servicing other than that described in this manual, the instrument should be sent to one of the Brush service facilities (listed on the Warranty page), where it can be restored to original condition. See Shipping Instructions following the Table of Contents.

The left side chassis (high gain section) of this amplifier has five (5) soldered connections which may be serviced in the field only by means of a special solder, special soldering equipment and special soldering technique. These connections are marked with green paint for easy identification, and called out on the schematic wiring diagram. If these connections must be broken and resoldered, special solder may be obtained from the Service Department, Brush Instruments, Division of Clevite Corporation, 3405 Perkins Avenue, Cleveland 14, Ohio.

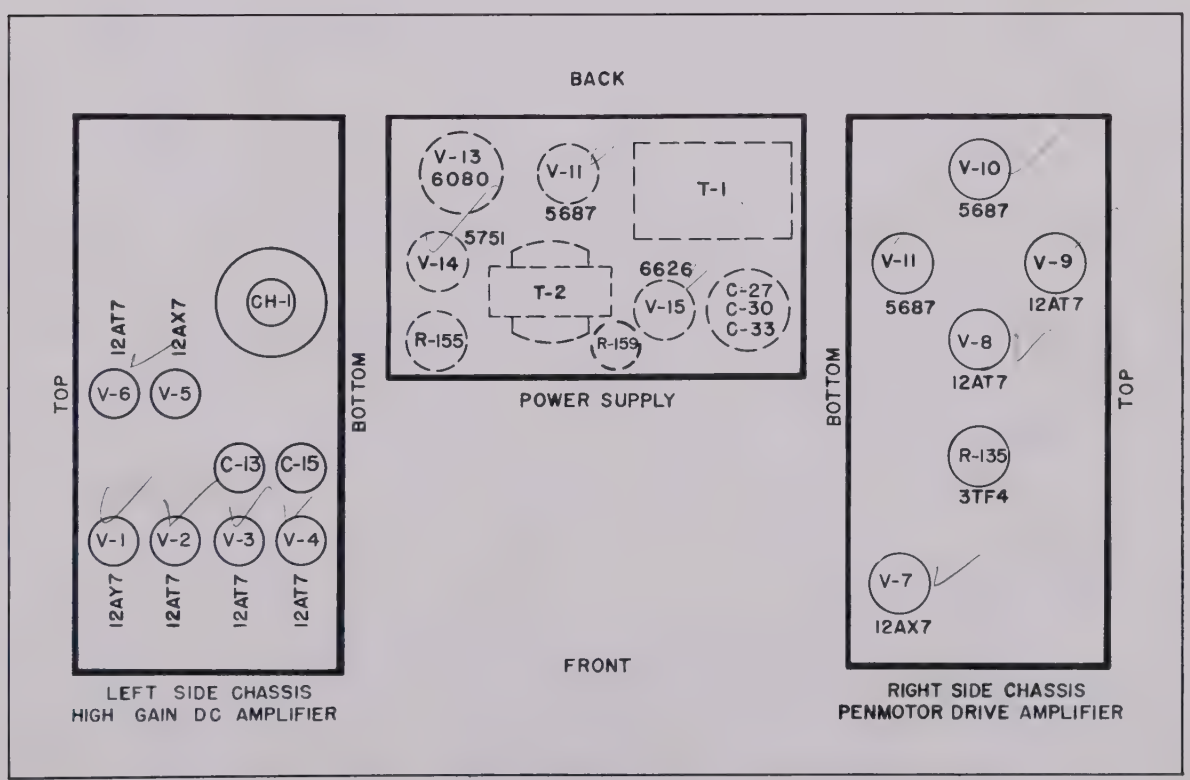


Fig. 11. Tube Layout.

TUBE REPLACEMENT

To replace any faulty tube, disconnect all cables and expose the chassis. If the amplifier is in a Portable Case, remove screws from the top and bottom of the case and remove the mounting screws from the front panel of the amplifier. If the amplifier is rack mounted, remove the mounting screws from the front panel, withdraw the amplifier from the rack, and remove the top portion of the wrap-around cover. Do not remove the screws securing the front panel to the amplifier chassis. In either case, all tubes will be exposed (Fig. 11).

LEFT SIDE CHASSIS

Following replacement of any tube in the left side chassis, follow the procedures described under "Plate Adjustment", "Signal Balance Adjustment", and "Grid Current Adjustment", below.

RIGHT SIDE CHASSIS

Following replacement of any tube in the d.c. amplifier section, the amplifier must be balanced, as described below:

1. Connect the OUTPUT connector (Fig. 1) with the oscillograph input connector by means of the amplifier-to-oscillograph signal cable.
2. Turn the SELECTOR switch (Fig. 2) to "pen drive", turn the VOLTS/CHART LINE switch (Fig. 2) to "off", and turn the amplifier POWER switch (Fig. 2) to "on". Allow 15 minutes for the amplifier to warm up.
3. Turn the oscillograph "on" at slow chart paper speed (to conserve chart paper).
4. Set the INPUT switch (Fig. 2) in the "balanced" position.
5. Turn the pen drive CALIBRATION control (Fig. 2) full clockwise, and bring the oscillograph pen approximately to chart center by means of the TUBE ADJUST control (Fig. 1) on the rear panel of the amplifier.
6. Turn the BALANCE control, on the rear panel of the amplifier (Fig. 1), to its extreme counterclockwise position. Rapidly rotate the CALIBRATION control (Fig. 2), counterclockwise, then clockwise, while turning the BALANCE control slowly clockwise until no pen deflection is noted.
7. Center the pen on the chart by means of the TUBE ADJUST control on the rear panel of the amplifier (Fig. 1).

POWER SUPPLY CHASSIS

Following the replacement of any tube in the power supply chassis (Fig. 11), adjust +B voltage to 235 volts by means of the potentiometer control R-155 (measured from the junction of C-28 and R-156 to pin 5 of the 6626 tube V-15.

Following any tube replacement in the High Gain D.C. Amplifier, install the wrap-around cover (if any) on the amplifier, and return the amplifier to its rack or Portable Case.

PLATE ADJUSTMENT

1. Connect the amplifier to an appropriate power source, turn the POWER switch (Fig. 2) to the "on" position, and allow 15 minutes for the unit to warm up.
2. Turn the SELECTOR switch (Fig. 2) to the "pen drive" position and connect the oscillograph to an appropriate power source. Turn the oscillograph "on" and adjust the pen to the center line of the chart by means of the PEN BIAS control (Fig. 2). Turn the oscillograph "off".
3. Place an open, shielded, GR type connector (supplied with the amplifier) over the high gain INPUT terminals (Fig. 2). See that the "G" on the connector is positioned over the "ground" terminal.
4. Turn the pen drive CALIBRATION control (Fig. 2) fully clockwise, and set the MILLIVOLTS/CHART LINE switch in the ".1" position.
5. Set SELECTOR switch (Fig. 2) in the "adjust" position and, using a d.c. vacuum tube voltmeter (VTVM), measure the d.c. voltage from chassis (ground) to pin 1, then from chassis to pin 6 of the 12AT7 tube (V-4). See Figure 11. If the amplifier is balanced (as indicated by a zero reading on the voltmeter), no further plate adjustment is necessary. If readings other than zero are noted, proceed as described in steps 6 through 8, below.
6. Alternately measure d.c. voltage from chassis to pin 1, then from chassis to pin 6 of the 12AT7 tube (V-4), as described in step 5, above, setting the AMPLIFIER ADJUST control (Fig. 2) as necessary to produce equal d.c. voltages.
7. By means of the PLATE ADJUST control (Fig. 1) on the rear panel of the amplifier, adjust the d.c. voltage from chassis to pin 1 of the 12AT7 tube (V-4) to zero (0) volts, ± 1 volt.
8. Repeat steps 6 and 7, above, as necessary to produce zero (0) voltmeter readings from chassis to pin 1 and from chassis to pin 6 of the 12AT7 tube (V-4).

SIGNAL BALANCE ADJUSTMENT

1. With the High Gain D.C. Amplifier enclosed in a wrap-around cover or Portable Case to prevent stray noise pickup, connect the amplifier to the oscillograph with the cable supplied.
2. With the SELECTOR switch (Fig. 2) in the "adjust" position, turn the oscillograph "on" and bring the pen approximately to chart center by means of the AMPLIFIER ADJUST control (Fig. 2).
3. Turn the MILLIVOLTS/CHART LINE switch (Fig. 2) alternately to the "off" and "calibrate" positions, recording the average deflection of the oscillograph pen trace for future reference.

Average pen deflection in step 3, above, must be in excess of 20 chart lines (mm). If the average deflection is less than 20 chart lines (mm), check the voltage output of the internal mercury cell with an accurate voltmeter. If the voltage output is not 1.35 volts $\pm 1\%$, replace the cell and repeat step 3.

4. Turn the SELECTOR switch (Fig. 2) to the "high gain" position and move the oscillograph pen trace to the left side of the chart paper with the PEN BIAS control (Fig. 2).
5. Set the MILLIVOLTS/CHART LINE switch (Fig. 2) in the "calibrate" position and, by means of the SIGNAL BALANCE control on the rear of the amplifier (Fig. 1), adjust the pen to the average pen deflection noted in step 3, above.
6. Set the MILLIVOLTS/CHART LINE switch (Fig. 2) in the ".1" position and return the pen to the center line of the chart by means of the PEN BIAS control (Fig. 2).

GRID CURRENT ADJUSTMENT

For adjustment of grid current, the High Gain D.C. Amplifier must be enclosed in a wrap-around cover or Portable Case to prevent stray noise pickup, and the amplifier must be connected to the oscillograph with the cable supplied. An open, shielded, GR type connector must be placed over the high gain INPUT terminals (Fig. 2), as described under "Plate Adjustment", above. For adjustment of grid current, proceed as follows:

1. With the SELECTOR switch (Fig. 2) in the "adjust" position, turn the oscillograph "on" and bring the pen approximately to chart center by means of the AMPLIFIER ADJUST control (Fig. 2).
2. Turn the SELECTOR switch (Fig. 2) to the "pen drive" position. If necessary, center the pen on the chart by means of the PEN BIAS control (Fig. 2).
3. Turn the SELECTOR switch (Fig. 2) to the "high gain" position, and set the MILLIVOLTS/CHART LINE switch (Fig. 2) in the "calibrate" position. Adjust the high gain CALIBRATION control (Fig. 2) to produce a pen deflection of 20 chart lines (mm).
4. Set the MILLIVOLTS/CHART LINE switch (Fig. 2) in the ".1" position and center the pen trace on the chart paper by means of the GRID CURRENT control (Fig. 1) on the rear panel of the amplifier.
5. Set the MILLIVOLTS/CHART LINE switch (Fig. 2) in the "calibrate" position, and adjust the high gain CALIBRATION control (Fig. 2) as necessary to produce a pen deflection of 20 chart lines (mm). If necessary repeat steps 1 through 4, above.

MODIFICATION OF POWER TRANSFORMER CONNECTIONS FOR OPERATION AT 95 TO 115 VOLTS

The Brush High Gain D.C. Amplifier is normally wired to operate on a power line voltage of from 105 to 125 volts. If the available power source is from 95 to 115 volts, a slight modification in the wiring of the power transformer (T-1) will adapt the amplifier to operation from such a power source. To make this modification, proceed as follows:

1. Disconnect the input power lead and capacitor lead from terminal "3" of the power transformer (T-1). Connect these two leads to terminal "2" of the power transformer. Refer to the Tube Layout (Fig. 11) and to the Schematic Diagram.
2. Re-solder to terminal "3" of the power transformer (T-1) that lead connecting terminal "3" to the separate filament transformer (T-2).

The above modification will be made at the factory if requested at time of ordering.

TROUBLE SHOOTING

The chart below lists symptoms and probable causes of improper operation of the amplifier, or failure of the amplifier to operate, as well as probably remedies for unsatisfactory operating conditions.

The conditions described in the chart are for a High Gain D.C. Amplifier Model RD 5615 00, connected to a correctly adjusted, operating Brush oscillograph, and operating from a 60 cps 115 volt power source. Procedures suggested in the "Remedy" column may be performed by operating personnel.

GENERAL

SYMPTOM	CAUSE	REMEDY
1. Amplifier does not operate; pilot lamp does not light.	a. Power cable disconnected. b. No power line voltage. c. Fuse open.	a. Connect power cable. b. Connect to proper power source. c. Replace fuse.
2. Amplifier does not operate; pilot lamp lights.	a. Defective cabling to oscillograph. b. Defective 6BW4, 6080, 5751, or 12AT7 tubes. c. Defective 3TF4 ballast resistor.	a. Repair or replace cable. b. Locate and replace defective tubes. c. Replace defective ballast resistor.
MEDIUM GAIN D.C. AMPLIFIER SECTION		
1. Oscillograph pen off chart (SELECTOR switch in "pen drive" position, INPUT switch in "balanced" position).	a. Improper +B (plate) voltage. b. Inoperative 5687 tubes. c. Improperly adjusted A (BALANCE) control. d. Grounded output leads to penmotor. e. Defective components in medium gain d.c. amplifier section.	a. Adjust +B voltage to 235 volts, as described in Section V—Maintenance. b. Locate and replace defective tubes. c. Adjust as described in Operating Instructions. d. Locate and eliminate grounds. e. Locate and replace defective components.
2. Oscillograph pen on chart, but off center (SELECTOR switch in "pen drive" position, INPUT switch in "balanced" position.	a. Improperly adjusted A (BALANCE) control (pen less than 5 mm off center). b. Inoperative tube or defective components in medium gain d.c. amplifier section (pen more than 5 mm off center).	a. Adjust as described in Operating Instructions. b. Locate and replace defective tubes or components.

SYMPTOM	CAUSE	REMEDY
3. PEN BIAS control inoperative (SELECTOR switch in "pen drive" position, INPUT switch in "grounded" position).	a. Defective 3TF4 ballast resistor. b. Defective 12AX7 tube. c. Open or grounded lead from arm of PEN BIAS potentiometer to pin 7 of first stage tube (12AX7). d. Grounded taps in voltage divider.	a. Replace defective ballast resistor. b. Replace defective tube. c. Repair or replace lead. d. Locate and eliminate grounds.
4. Amplifier can be balanced, but drift exceeds ½ chart line (mm) per hour.	a. Plate voltage supply not regulating properly. b. Excessive line voltage variation. c. Grid current in 12AX7 tube (does not occur when pen is biased to right side of chart). d. Defective components in pen compensation (feedback) circuit.	a. Refer to "Power Supply Section," below. b. Connect amplifier to proper power source. c. Replace 12AX7 tube. d. Locate and replace defective components in pen compensation circuit.
5. Inadequate calibrate level in medium gain d.c. amplifier section (should exceed 21.7 volts across 1500 ohm resistance load when VOLTS/CHART LINE switch is in "calibrate" position and the pen drive CALIBRATION control is fully clockwise).	a. Weak 12AX7, 12AT7, or 5687 tubes. b. Dirty calibrate cell contacts. c. Defective mercury cell.	a. Replace defective tubes. b. Clean contacts. c. Replace defective cell.
6. 120 cps output indicated on oscillograph chart without input to amplifier.	a. Defective filter capacitor. b. Shorted 6080 tube. c. Inoperative 6626 or 12AX7 tube.	a. Replace filter. b. Replace defective tube. c. Replace defective tubes.
7. 60 cps output indicated on oscillograph chart without input to amplifier.	a. Cathode-to-heater leakage, any tube in medium gain d.c. amplifier section.	a. Locate and replace defective tube.
8. Random output indicated on oscillograph chart without input to amplifier.	a. Noisy 12AX7, 12AT7, or 5687 tube. b. Noisy components. c. Oscillation in 6626 tube.	a. Replace defective tube. b. Replace defective components. c. Replace defective tube.
9. Incorrect sensitivity for VOLTS/CHART LINE attenuator steps.	a. Defective attenuator resistors. b. Grounded components in attenuator assembly.	a. Locate and replace defective resistors. b. Locate and eliminate grounds.

SYMPTOM	CAUSE	REMEDY
10. Amplifier cannot be frequency compensated.	a. Improper compensation procedure. b. Defective potentiometer, switch, or capacitor in compensation circuit. c. Defective 12AX7, 12AT7, or 5687 tube.	a. Refer to Operating Instructions for proper procedure. b. Locate and replace defective components. c. Replace defective tube.
11. Poor d.c. linearity.	a. Weak 12AX7, 12AT7, or 5687 tube. b. Defective penmotor.	a. Locate and replace defective tube. b. Replace penmotor or oscillograph.
HIGH GAIN D.C. AMPLIFIER SECTION		
1. Pen offset with MILLIVOLTS/CHART LINE switch in ".1" position. (Pen moves more than 1 mm from chart center when SELECTOR switch is turned from "adjust" position to "high gain" position.)	a. Unwanted extraneous signal feeding into correction amplifier circuit. b. Defective 12AY7 or 12AT7 tubes. c. Joints requiring special solder improperly soldered. d. Defective solder joint in attenuator assembly. e. Chopper operating improperly. f. Capacitor at input of correction amplifier (.02 mfd) picks up a.c. field. g. Leads to and from correction amplifier, as well as internal leads, dressed too close to a.c. fields. h. Defective coupling capacitors.	a. Remove amplifier from source of unwanted signals. b. Replace defective tubes. c. Contact Service Department, Brush Instruments, for proper soldering procedure. d. Resolder. e. Repair or replace chopper. f. Dress circuit components to eliminate a.c. pickup. g. Dress leads and components to avoid coupling to a.c. fields. h. Replace defective capacitors.
2. Preamplifier cannot be balanced with SELECTOR switch in "adjust" position, MILLIVOLTS/CHART LINE switch in ".1" position, and high gain CALIBRATION control fully counterclockwise.	a. Defective tubes in preamplifier (12AY7 or 12AT7). b. Inoperative AMPLIFIER ADJUST control. c. Open resistor from arm of AMPLIFIER ADJUST potentiometer to —B. d. Defective resistor in preamplifier, particularly between first and second stages.	a. Replace defective tubes. b. Replace defective control. c. Replace defective resistor. d. Replace defective resistor.

SYMPTOM	CAUSE	REMEDY
	e. Improper contact at tube socket.	e. Clean or replace socket.
	f. Broken wiring to tube socket.	f. Repair broken wiring.
3. Preamplifier can be balanced with SELECTOR switch in "adjust" position, but not with SELECTOR switch in "high gain" position.	a. Inoperative .02 mfd capacitor at input to correction amplifier, or defective coupling capacitors in correction amplifier.	a. Replace defective capacitors.
	b. Defective tubes in correction amplifier circuit.	b. Replace defective tubes.
	c. Inoperative or improperly adjusted SIGNAL BALANCE control.	c. Replace or adjust control. For adjustment procedure, refer to Operating Instructions.
4. Preamplifier can be balanced with SELECTOR switch in "adjust" or "high gain" position, but drifts excessively.	a. Inoperative 100 mfd. capacitor from +B to ground.	a. Replace defective capacitor.
	b. Inoperative 8 mfd. capacitor at plate supply of 5751 tube in correction amplifier circuit.	b. Replace defective capacitor.
	c. Unstable +B (plate) voltage.	c. Refer to "Power Supply Section", below.
	d. Excessive grid current in 12AY7 tube of preamplifier.	d. Replace defective tube.
	e. Excessive grid current in 5751 tube of correction amplifier.	e. Replace defective tube.
5. Amplifier drifts excessively with line voltage variation.	a. Gain of correction amplifier considerably less than 25,000.	a. Repair correction amplifier for proper gain. (Check for grid current in 5751 tube, or for inoperative 8 mfd. capacitor in plate circuit of first stage.)
	b. Improperly regulated +B (plate) supply voltage.	b. Refer to "Power Supply Section", below.
	c. Improperly adjusted SIGNAL BALANCE control.	c. Adjust as described in Operating Instructions.
6. Excessive noise or hum output (350 millivolts maximum).	a. Noisy resistors, particularly in first stage of preamplifier.	a. Replace noisy resistors.
	b. Leads to chopper socket dressed improperly.	b. Dress leads to produce minimum hum output.
	c. Defective ground connection at input of preamplifier.	c. Locate and repair defective connection.
	d. Inadequate shielding over precision resistor assembly in first stage of preamplifier.	d. Install proper shielding.

SYMPTOM	CAUSE	REMEDY
	e. Open circuit in chopper socket ground.	e. Repair broken connection.
	f. Noisy 12AT7 tube, especially with line voltage variation.	f. Replace defective tube.
	g. Excessive voltage from +B to −B (shorted 6080 tube).	g. Replace defective tube.
	h. Oscillation in correction amplifier circuit (improperly dressed leads).	h. Dress leads to eliminate oscillation.
7. Random output with no input to high gain d.c. amplifier section.	a. Noisy resistors (2.5M or 500K) in first stage of preamplifier circuit.	a. Locate and replace noisy resistors.
	b. Intermittent capacitor (100 mfd) from +B to ground.	b. Replace defective capacitor.
	c. Correction amplifier triggered by power line transients.	c. Install filter at correction amplifier input. (For information contact the Service Department, Brush Instruments.)
8. Microphonic output when amplifier is jarred, with no input to high gain d.c. amplifier section.	a. Intermittent or improperly mounted capacitor (.02 mfd) at input to correction amplifier circuit.	a. Re-mount or replace capacitor. See that capacitor is mechanically secure.
	b. Mechanically unstable components in MILLIVOLTS/CHART LINE attenuator.	b. Dress leads and components to provide mechanical stability.
	c. Dirty components on MILLIVOLTS/CHART LINE switch.	c. Clean contacts and lubricate switch detent mechanism.
	d. Microphonic tubes in high gain d.c. amplifier section.	d. Locate and replace microphonic tubes.
POWER SUPPLY SECTION		
1. Variation in +B to −B regulated voltage.	a. Insufficient power line voltage.	a. Connect amplifier to proper power source.
	b. Inoperative 6626, 6080, 5751, or 6BW4 tube.	b. Locate and replace defective tube.
	c. Oscillation in +B (plate supply) voltage (defective 6626 tube).	c. Replace defective 6626 tube.
	d. Open output filter capacitor.	d. Replace defective filter capacitor.
	e. Insufficient heater voltage to 6080 tube (defective transformer).	e. Replace defective transformer.

It is recommended that, for major servicing or repairs, the instrument be returned to a factory service station where facilities are available to restore it to its original condition. In the event that this is impractical or the repair is of a minor nature, the following photographs, parts lists, and schematic diagram are designed to assist in servicing and repairing. In order to assure prompt and satisfactory delivery of replacement parts, it is very necessary that you include the following information with your order:

1. The name and serial number of the instrument for which the parts are to be used. For example,

   "High Gain D.C. Amplifier Model RD 5615 00, Serial No. 123".

2. The following specific information on the desired parts:
   Description
   Value (electrical)
   Brush Part No.

NOTE: Do not use the SYMBOL NO. for identifying desired parts on your order.

PARTS IDENTIFICATION

Components of the High Gain D.C. Amplifier may be identified by means of Figures 12 through 21 (below). The symbols appearing on these illustrations are correlated with the Parts List and the Schematic Diagram. In addition to identification of parts, Figure 18 includes a color code for connection of wiring to the printed wiring board in the medium gain d.c. amplifier section.

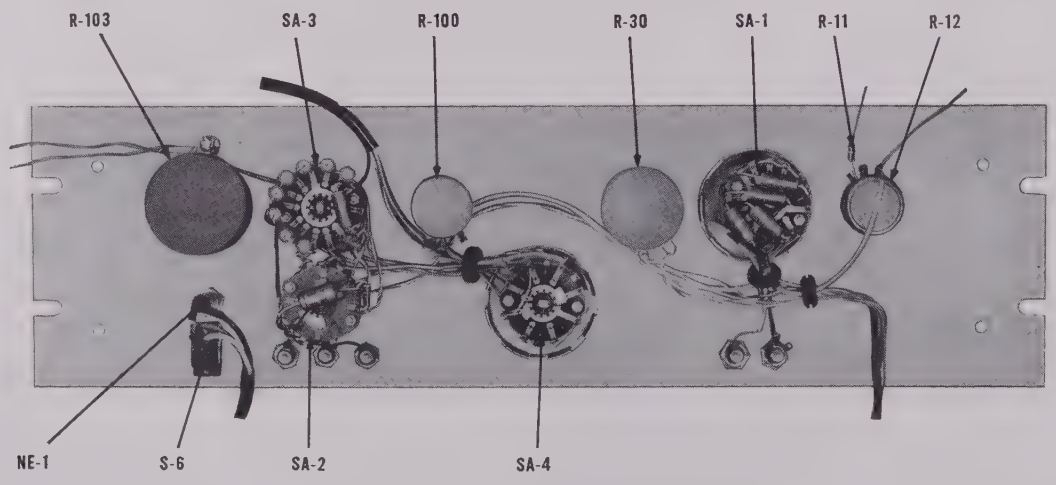


Fig. 12. Rear View—Front Panel Assembly.

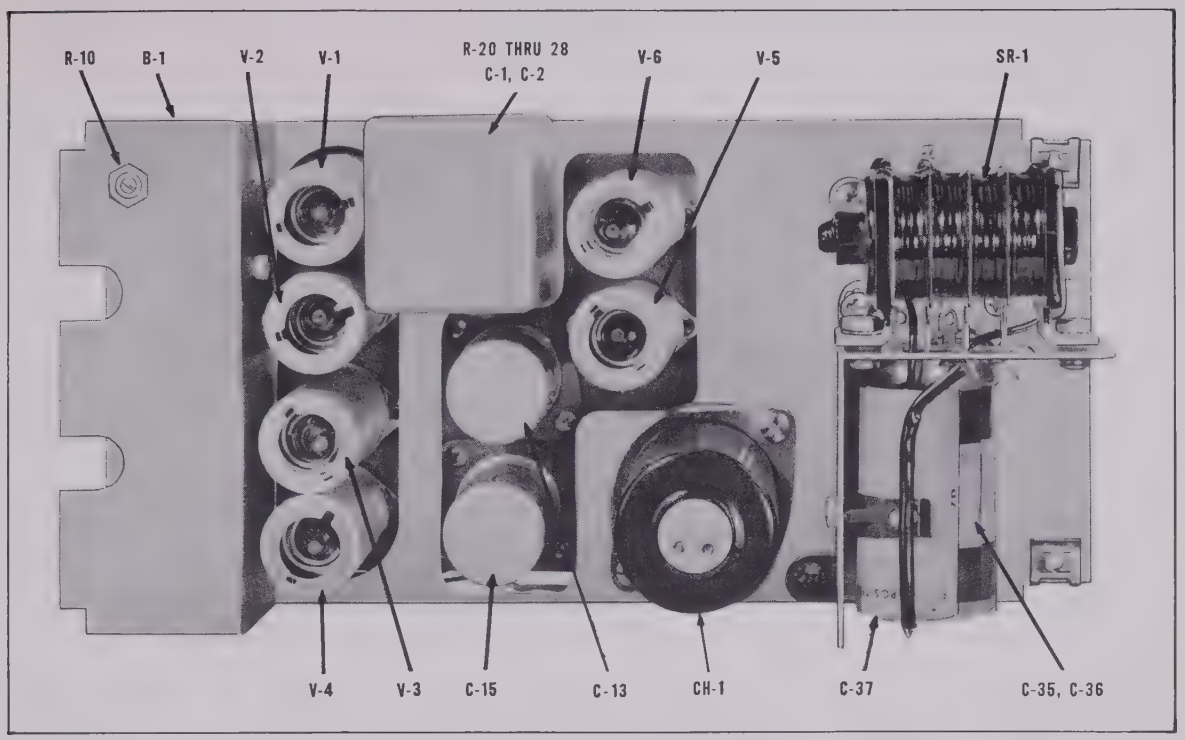


Fig. 13. Inside View—Left Side Chassis.

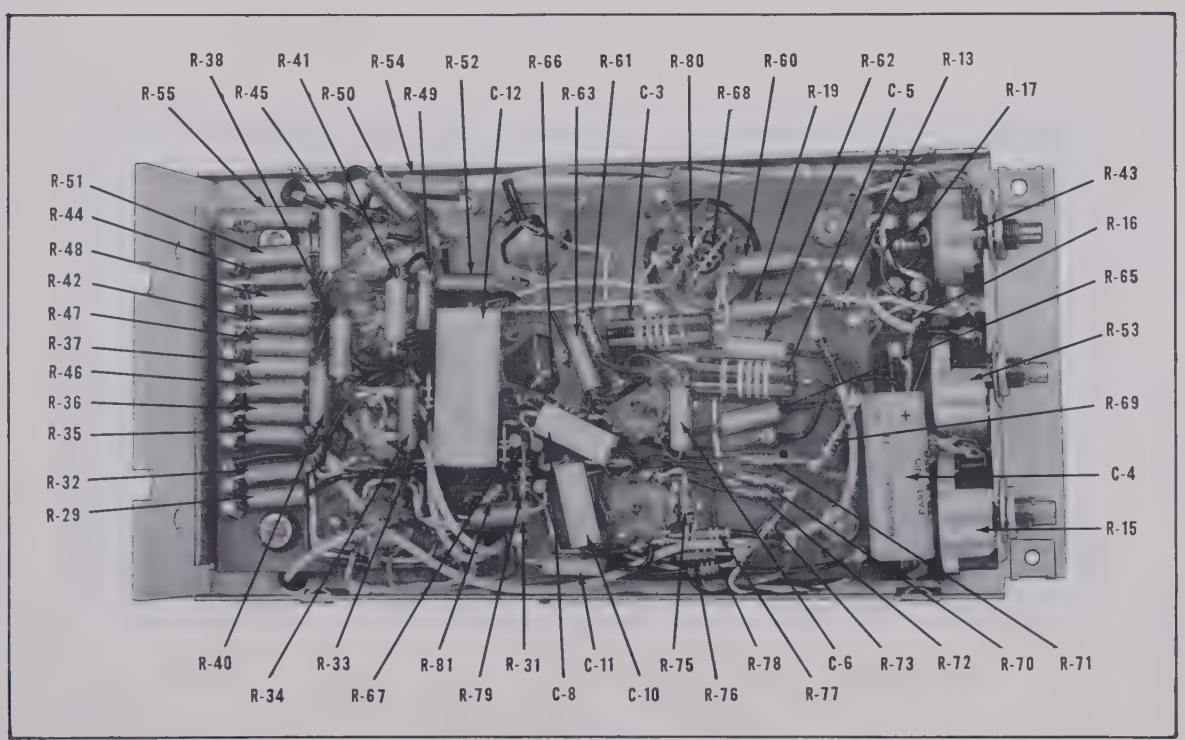


Fig. 14. Outside View—Left Side Chassis.

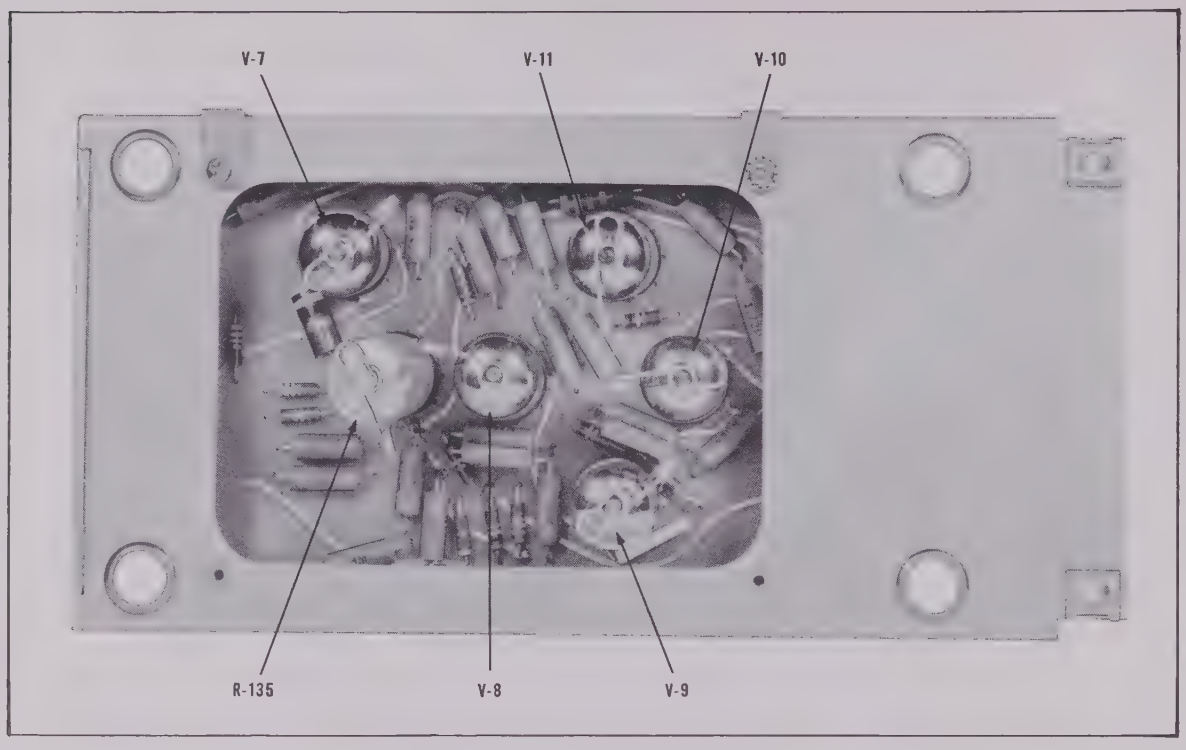


Fig. 15. Inside View—Right Side Chassis.

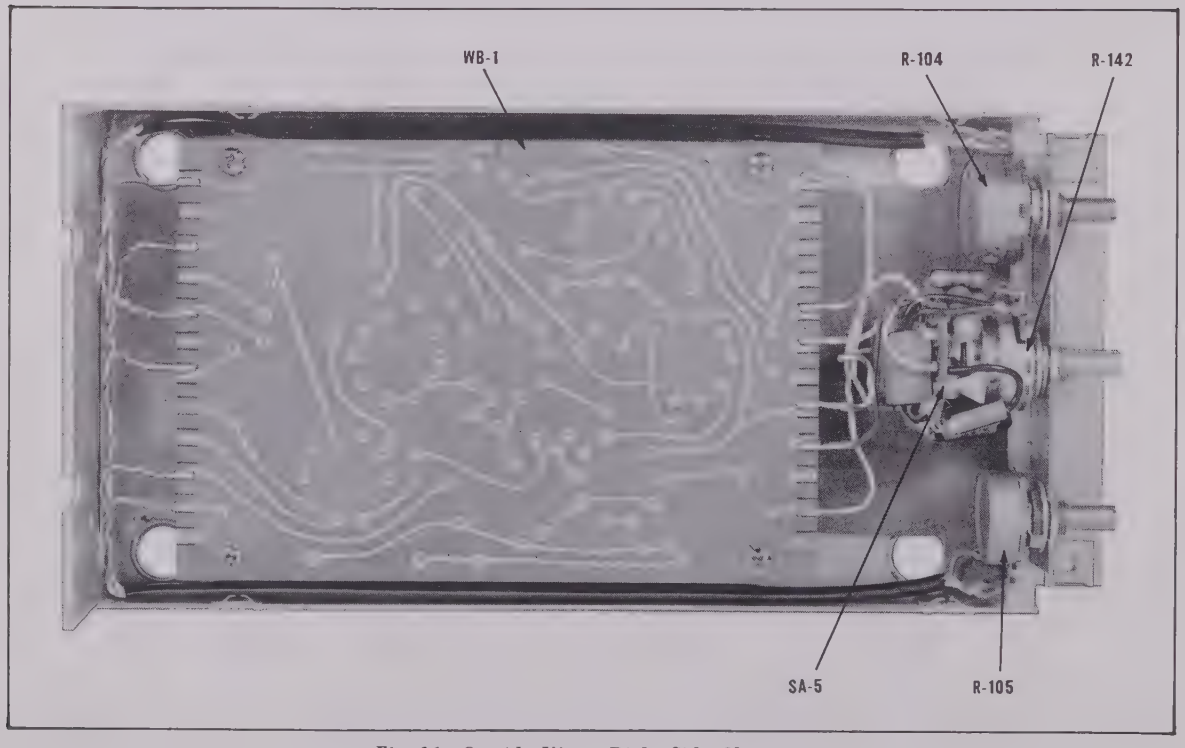


Fig. 16. Outside View—Right Side Chassis.

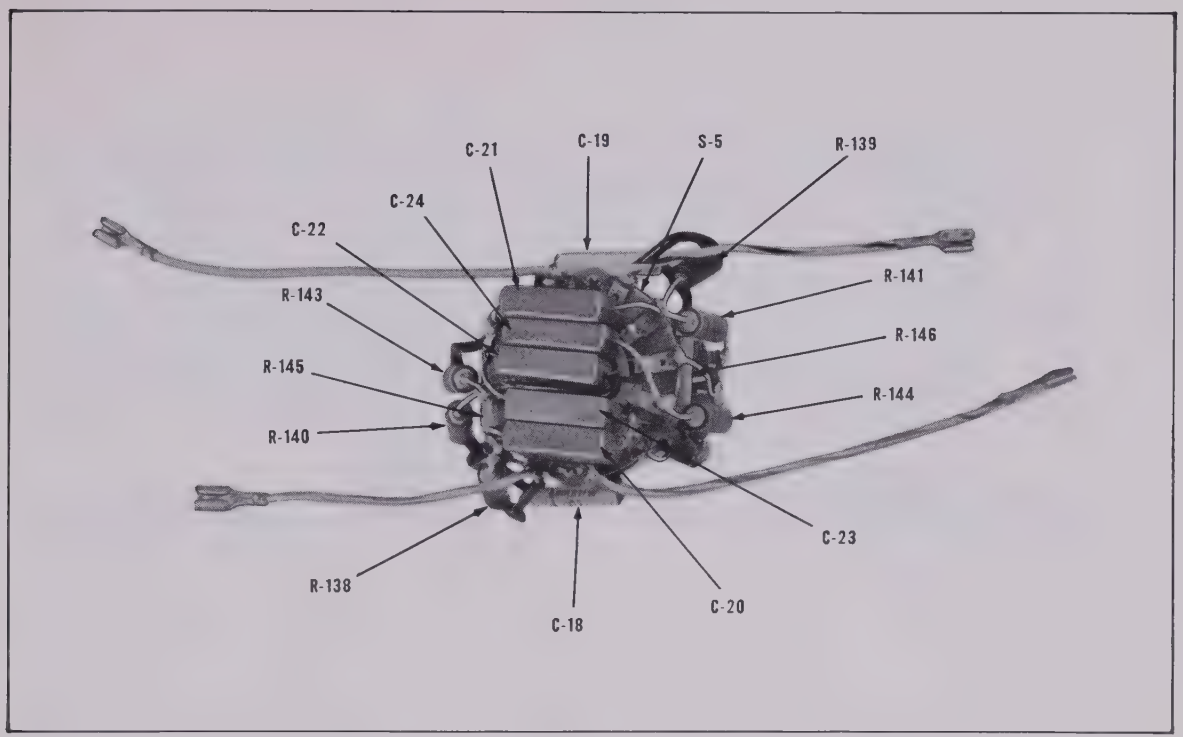


Fig. 17. Pen Compensation Network.

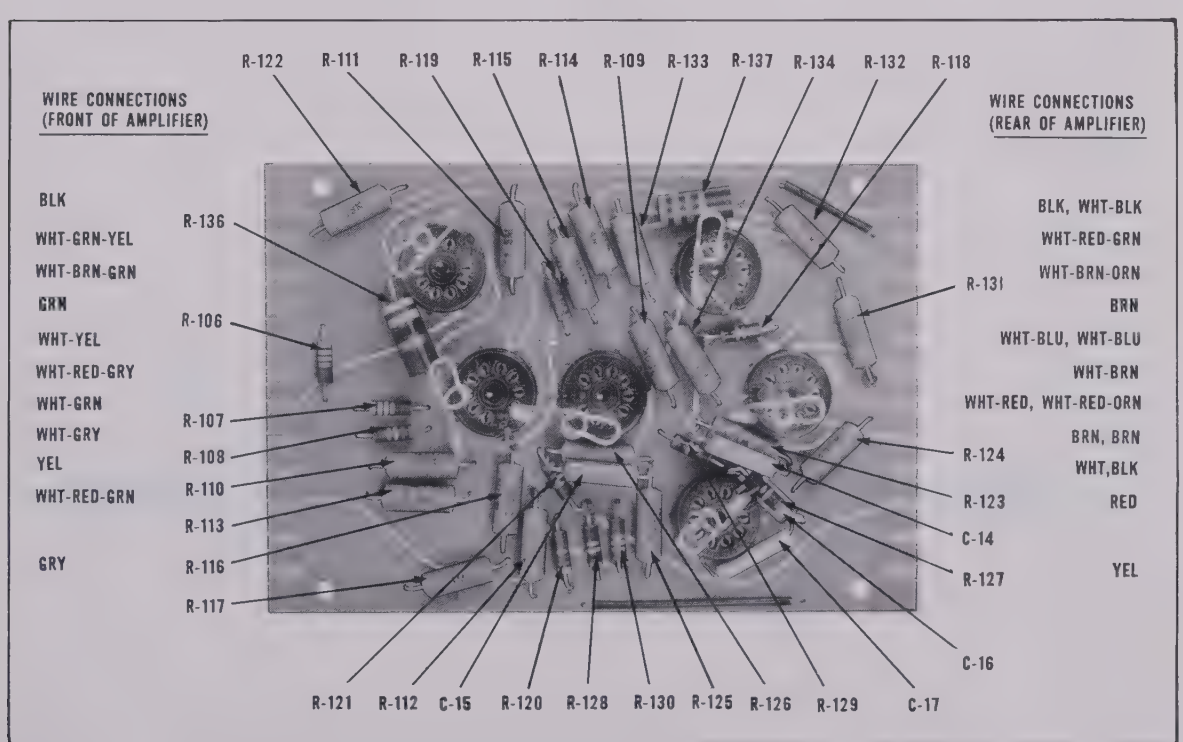


Fig. 18. Printed Wiring Board (Less Tubes).

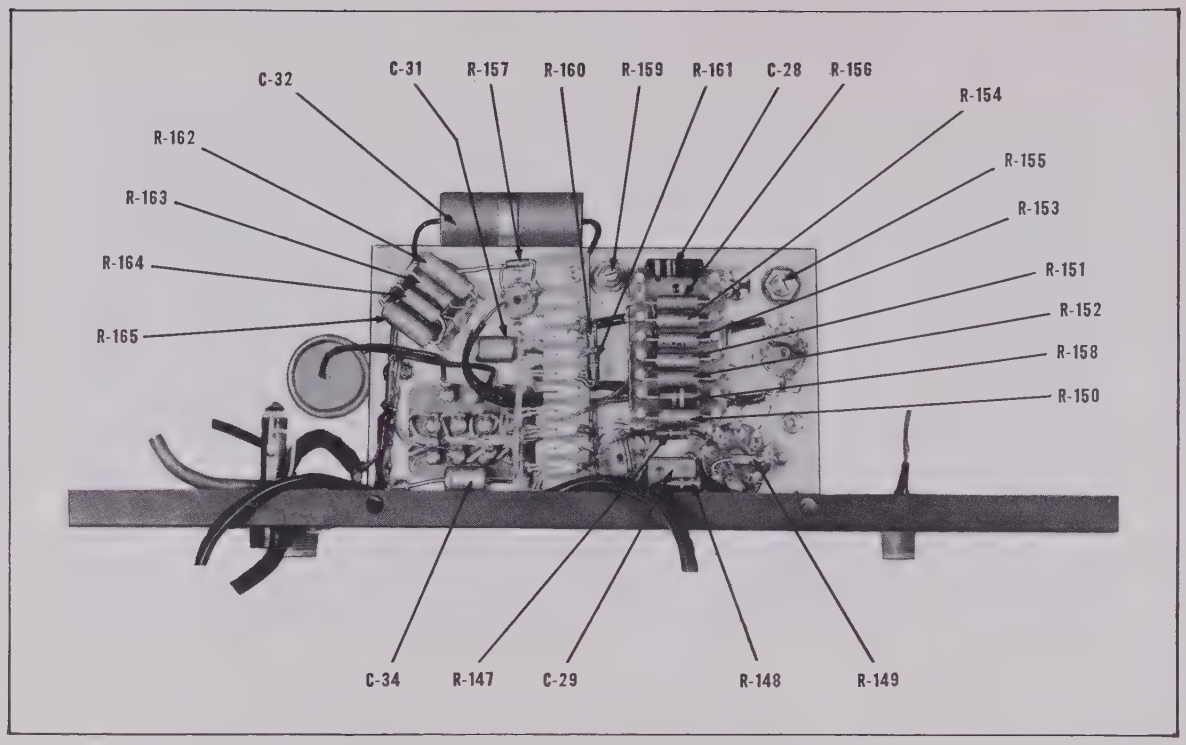


Fig. 19. Top View—Power Supply Chassis.

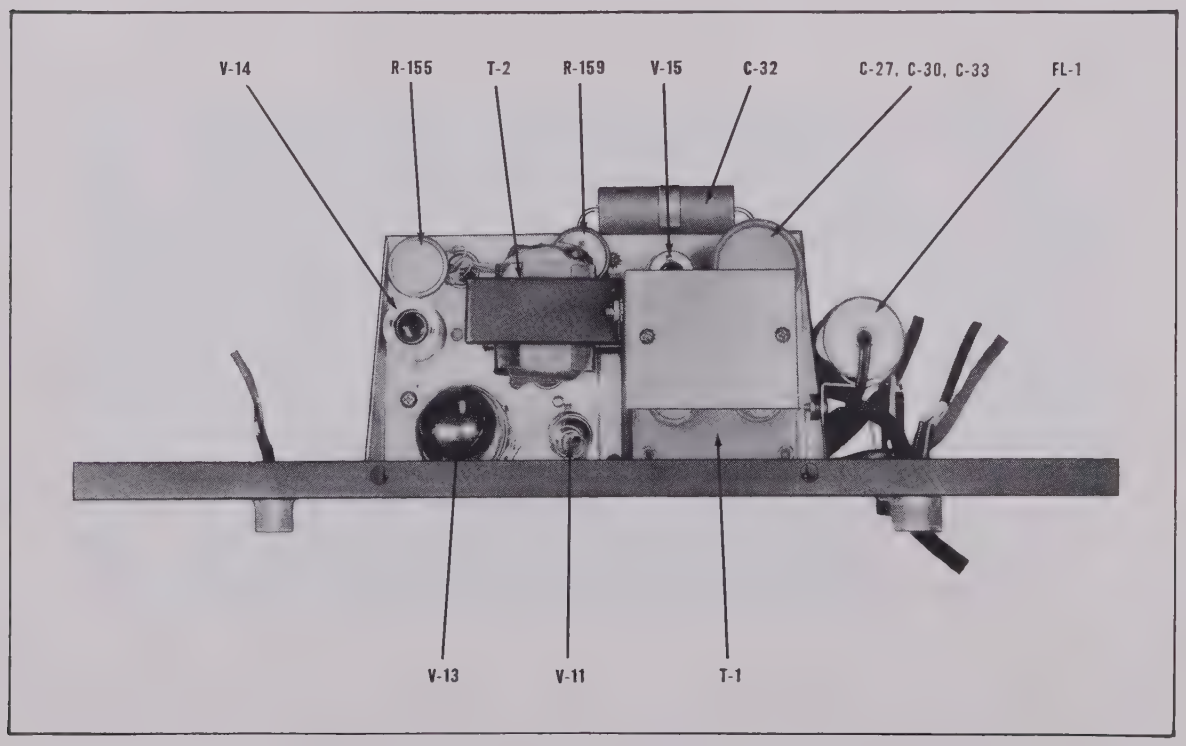


Fig. 20. Bottom View—Power Supply Chassis.

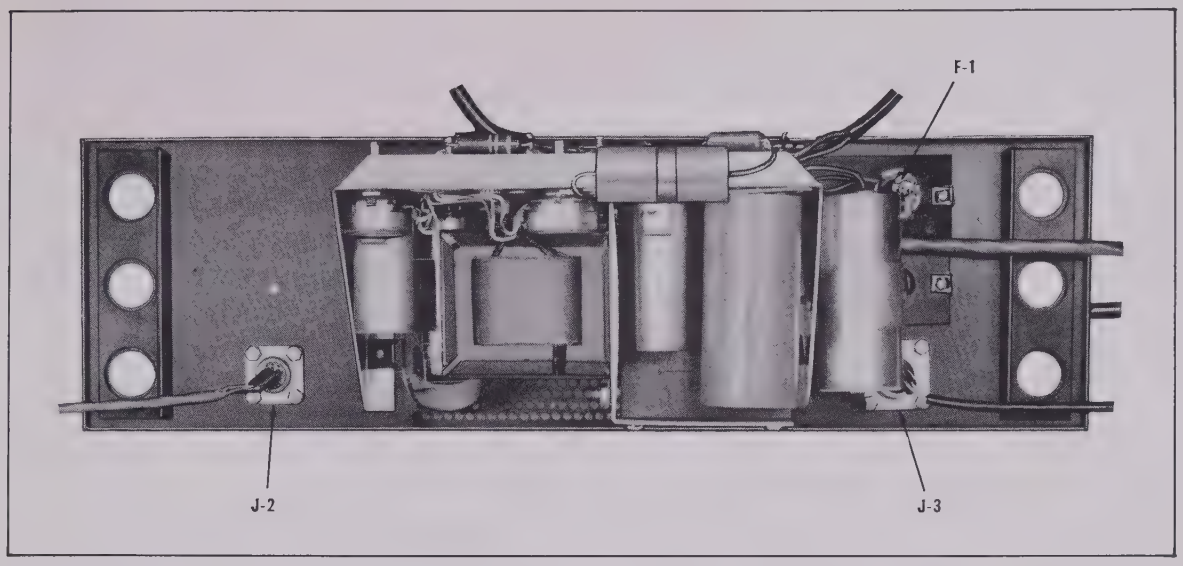


Fig. 21. Inside View—Rear Panel Assembly.

PARTS LIST

SYMBOL	DESCRIPTION	VALUE	BRUSH PART NO.
B-1	Mercury Cell	1.35V, ± 1%	1-125398-1
C-1	Capacitor, Mica	30 mmfd, ± 5%, 500V	5-117264-300
C-2	Capacitor, Mica	30 mmfd, ± 5%, 500V	5-117264-300
C-3	Capacitor, Paper	.022 mfd, ± 10%, 200V	10-217608-223
C-4	Capacitor, Electrolytic	8 mfd, 450V	100-120470-805
C-5	Capacitor, Paper	.047 mfd, ± 10%, 400V	10-217413-473
C-6	Capacitor, Paper	.001 mfd, ± 10%, 600V	10-217260-102
C-7	Capacitor, Electrolytic	20 mfd, 450V	117717-206
C-8	Capacitor, Paper	.047 mfd, ± 10%, 400V	10-125905-473
C-9	Capacitor, Electrolytic	20 mfd, 450V	117717-206
C-10	Capacitor, Paper	.047 mfd, ± 10%, 400V	10-125905-473
C-11	Capacitor, Mica	.001 mfd, ± 5%, 500V	5-117265-102
C-12	Capacitor, Paper	2 mfd, ± 10%, 200V	10-125904-205
C-13	Capacitor, Paper	.05 mfd, ± 10%, 400V	10-120555-503
C-14	Capacitor, Mica	68 mmfd, ± 5%, 500V	5-117264-680
C-15	Capacitor, Mica	68 mmfd, ± 5%, 500V	5-117264-680
C-16	Capacitor, Mica	470 mmfd, ± 5%, 500V	5-117264-471
C-17	Capacitor, Mica	.0033 mfd, ± 5%, 500V	5-117265-332
C-18	Capacitor, Mylar	.01 mfd, ± 20%, 200V	127714-103
C-19	Capacitor, Mylar	.01 mfd, ± 20%, 200V	127714-103
C-20	Capacitor, Mica	680 mmfd, ± 5%, 500V	5-117264-681
C-21	Capacitor, Mica	680 mmfd, ± 5%, 500V	5-117264-681
C-22	Capacitor, Mica	680 mmfd, ± 5%, 500V	5-117264-681
C-23	Capacitor, Mica	680 mmfd, ± 5%, 500V	5-117264-681
C-24	Capacitor, Mica	680 mmfd, ± 5%, 500V	5-117264-681
C-25	Capacitor, Mica	330 mmfd, ± 5%, 500V	5-117264-331
C-27	Capacitor, Electrolytic (⅓ Triple Section)	20 mfd, 450V	117718-206
C-28	Capacitor, Paper	.01 mfd, ± 10%, 400V	10-217413-103
C-29	Capacitor, Mica	.0022 mfd, ± 10%, 500V	10-117265-222

PARTS LIST (Cont'd)

SYMBOL	DESCRIPTION	VALUE	BRUSH PART NO.
C-30	Capacitor, Electrolytic (⅓ Triple Section)	20 mfd, 450V	(Part of C-27)
C-31	Capacitor, Paper	.25 mfd, 200V	10-120554-254
C-32	Capacitor, Electrolytic	100 mfd, 250V	127747
C-33	Capacitor, Electrolytic (⅓ Triple Section)	20 mfd, 450V	(Part of C-27)
C-34	Capacitor, Paper	.25 mfd, 200V	10-120554-254
C-35	Capacitor, Electrolytic	1000 mfd, 15V	100-120596-108
C-36	Capacitor, Electrolytic (½ Dual Section)	1000 mfd, 15V	100-120471-108
C-37	Capacitor, Electrolytic (½ Dual Section)	1000 mfd, 15V	(Part of C-36)
CH-1	Chopper		120379-1
F-1	Fuse	Type 3AG, "Quick Acting", 2A, 250V	102625
FL-1	Filter, Power Line		123361
J-1	Binding Post (2)	GR Type	119741-3
J-2	Binding Post (3)	GR Type	119741-3
J-3	Connector, Female, 6 Pin	AN Type—AN3102A-14S-6S	119990
NE-1	Neon Lamp		126621
P-1	Connector, Male, 3 Pin	AN Type—AN3102A-10SL-3P	121274
P-2	Cable, Power Input		126551-6
R-1	Resistor, Precision	500K, ± 1%, ½W	1-117801-5003
R-2	Resistor, Precision	1.0M, ± 1%, ½W	1-117801-1004
R-3	Resistor, Precision	800K, ± 1%, ½W	1-117801-8003
R-4	Resistor, Precision	250K, ± 1%, ½W	1-117801-2503
R-5	Resistor, Precision	900K, ± 1%, ½W	1-117801-9003
R-6	Resistor, Precision	58.5K, ± 1%, ½W	1-117801-5852
R-7	Resistor, Precision	52.5K, ± 1%, ½W	1-117801-5252
R-8	Resistor, Precision	5.0M, ± 1%, ½W	1-117801-5004
R-9	Resistor, Precision	7.47K, ± 1%, ½W	1-117801-7471
R-10	Resistor, Variable	2.5M	30-124788-255
R-11	Resistor, Composition	1.5M, ± 5%, ½W	5-115557-155
R-12	Resistor, Variable	2.5M	19-211473-255
R-13	Resistor, Composition	22M, ± 5%, ½W	5-115557-226
R-14	Resistor, Composition	620K, ± 5%, ½W	5-115557-624
R-15	Resistor, Variable	500 ohms	10-120595-501
R-16	Resistor, Composition	220K, ± 5%, ½W	5-115557-224
R-17	Resistor, Composition	100 ohms, ± 5%, ½W	5-115557-101
R-18	Resistor, Composition	100 ohms, ± 5%, ½W	5-115557-101
R-19	Resistor, Composition	4.7M, ± 5%, ½W	5-115557-475
R-20	Resistor, Precision	250K, ± 1%, ½W	1-117802-2503
R-21	Resistor, Precision	1.2K, ± 1%, ½W	1-117802-1201
R-22	Resistor, Precision	390K, ± 1%, ½W	1-117802-3903
R-23	Resistor, Precision	1.2K, ± 1%, ½W	1-117802-1201
R-24	Resistor, Precision	250K, ± 1%, ½W	1-117802-2503
R-25	Resistor, Precision	2.5M, ± 1%, ½W	1-117802-2504
R-26	Resistor, Precision	500K, ± 1%, ½W	1-117802-5003
R-27	Resistor, Precision	500K, ± 1%, ½W	1-117802-5003
R-28	Resistor, Precision	2.5M, ± 1%, ½W	1-117802-2504
R-29	Resistor, Precision	100K, ± 1%, ½W	1-117802-1003
R-30	Resistor, Variable, 10 Turn	2K	119048
R-31	Resistor, Precision	15K, ± 1%, ½W	1-117802-1502
R-32	Resistor, Precision	100K, ± 1%, ½W	1-117802-1003
R-33	Resistor, Composition	1.2M, ± 5%, ½W	5-115557-125
R-34	Resistor, Precision	1.1M, ± 1%, ½W	1-117802-1104
R-35	Resistor, Precision	510K, ± 1%, ½W	1-117802-5103
R-36	Resistor, Precision	18K, ± 1%, ½W	1-117802-1802
R-37	Resistor, Precision	510K, ± 1%, ½W	1-117802-5103
R-38	Resistor, Precision	1.1M, ± 1%, ½W	1-117802-1104

PARTS LIST (Cont'd)

SYMBOL	DESCRIPTION	VALUE	BRUSH PART NO.
R-39	Resistor, Composition	1.2M, ± 5%, ½W	5-115557-125
R-40	Resistor, Precision	100K, ± 1%, ½W	1-117802-1003
R-41	Resistor, Precision	1.1M, ± 1%, ½W	1-117802-1104
R-42	Resistor, Precision	300K, ± 1%, ½W	1-117802-3003
R-43	Resistor, Variable	25K	4-211473-253
R-44	Resistor, Precision	300K, ± 1%, ½W	1-117802-3003
R-45	Resistor, Precision	1.1M, ± 1%, ½W	1-117802-1104
R-46	Resistor, Precision	100K, ± 1%, ½W	1-117802-1003
R-47	Resistor, Precision	100K, ± 1%, ½W	1-117802-1003
R-48	Resistor, Precision	100K, ± 1%, ½W	1-117802-1003
R-49	Resistor, Precision	33K, ± 1%, ½W	1-117802-3302
R-50	Resistor, Precision	33K, ± 1%, ½W	1-117802-3302
R-51	Resistor, Precision	1.0M, ± 1%, ½W	1-117802-1004
R-52	Resistor, Precision	100K, ± 1%, ½W	1-117802-1003
R-53	Resistor, Variable	10K	10-120595-103
R-54	Resistor, Precision	2.0M, ± 1%, ½W	1-117802-2004
R-55	Resistor, Precision	1.0M, ± 1%, ½W	1-117802-1004
R-56	Resistor, Precision	50K, ± 1%, ½W	1-117801-5002
R-57	Resistor, Precision	30K, ± 1%, ½W	1-117801-3002
R-58	Resistor, Precision	10K, ± 1%, ½W	1-117801-1002
R-59	Resistor, Precision	10K, ± 1%, ½W	1-117801-1002
R-60	Resistor, Composition	4.7M, ± 5%, ½W	5-115557-475
R-61	Resistor, Composition	4.7M, ± 5%, ½W	5-115557-475
R-62	Resistor, Precision	250K, ± 1%, ½W	1-117802-2503
R-63	Resistor, Precision	10K, ± 1%, ½W	1-117802-1002
R-64	Resistor, Composition	1.0M, ± 5%, ½W	5-115557-105
R-65	Resistor, Precision	250K, ± 1%, ½W	1-117802-2503
R-66	Resistor, Composition	8.2K, ± 1%, ½W	5-115557-822
R-67	Resistor, Composition	10K, ± 5%, ½W	5-115557-103
R-68	Resistor, Composition	10 ohms, ± 5%, ½W	5-115557-100
R-69	Resistor, Composition	47K, ± 5%, ½W	5-115557-473
R-70	Resistor, Composition	1.0M, ± 5%, ½W	5-115557-105
R-71	Resistor, Composition	82K, ± 5%, ½W	5-115557-823
R-72	Resistor, Composition	2.2K, ± 5%, ½W	5-115557-222
R-73	Resistor, Composition	10K, ± 5%, ½W	5-115557-103
R-74	Resistor, Composition	4.7M, ± 5%, ½W	5-115557-475
R-75	Resistor, Composition	1.0M, ± 5%, ½W	5-115557-105
R-76	Resistor, Composition	1.0M, ± 5%, ½W	5-115557-105
R-77	Resistor, Composition	150K, ± 5%, ½W	5-115557-154
R-78	Resistor, Composition	2.2K, ± 5%, ½W	5-115557-222
R-79	Resistor, Composition	100K, ± 5%, ½W	5-115557-104
R-80	Resistor, Composition	10M, ± 5%, ½W	5-115557-106
R-81	Resistor, Composition	22M, ± 5%, ½W	5-115557-226
R-82	Resistor, Precision	350K, ± 0.5%, ½W	50-117802-3503
R-83	Resistor, Precision	1.0M, ± 0.5%, ½W	50-117802-1004
R-84	Resistor, Precision	2.5M, ± 0.5%, ½W	50-117802-2504
R-85	Resistor, Precision	1.25M, ± 0.5%, ½W	50-117802-1254
R-86	Resistor, Precision	750K, ± 0.5%, ½W	50-117802-7503
R-87	Resistor, Precision	250K, ± 0.5%, ½W	50-117802-2503
R-88	Resistor, Precision	125K, ± 0.5%, ½W	50-117802-1253
R-89	Resistor, Precision	75K, ± 0.5%, ½W	50-117802-7502
R-90	Resistor, Precision	25K, ± 0.5%, ½W	50-117802-2502
R-91	Resistor, Precision	25K, ± 0.5%, ½W	50-117802-2502
R-92	Resistor, Precision	25K, ± 0.5%, ½W	50-117802-2502
R-93	Resistor, Precision	25K, ± 0.5%, ½W	50-117802-2502

PARTS LIST (Cont'd)

SYMBOL	DESCRIPTION	VALUE	BRUSH PART NO.
R-94	Resistor, Precision	75K, ± 0.5%, ½W	50-117802-7502
R-95	Resistor, Precision	125K, ± 0.5%, ½W	50-117802-1253
R-96	Resistor, Precision	250K, ± 0.5%, ½W	50-117802-2503
R-97	Resistor, Precision	750K, ± 0.5%, ½W	50-117802-7503
R-98	Resistor, Precision	1.25M, ± 0.5%, ½W	50-117802-1254
R-99	Resistor, Precision	2.5M, ± 0.5%, ½W	50-117802-2504
R-100	Resistor, Variable	1.0M	2-212022-105
R-101	Resistor, Composition	2.7K, ± 5%, ½W	5-115557-272
R-102	Resistor, Composition	470K, ± 5%, ½W	5-115557-474
R-103	Resistor, Variable	50K	5-117686-503
R-104	Resistor, Variable	10K	20-125156-103
R-105	Resistor, Variable	3K	20-125156-302
R-106	Resistor, Composition	33K, ± 5%, ½W	5-115557-333
R-107	Resistor, Composition	33K, ± 5%, ½W	5-115557-333
R-108	Resistor, Composition	12K, ± 5%, ½W	5-115557-123
R-109	Resistor, Precision	250K, ± 1%, ½W	1-117802-2503
R-110	Resistor, Precision	250K, ± 1%, ½W	1-117802-2503
R-111	Resistor, Precision	2.5M, ± 1%, ½W	1-117802-2504
R-112	Resistor, Precision	350K, ± 1%, ½W	1-117802-3503
R-113	Resistor, Precision	2.5M, ± 1%, ½W	1-117802-2504
R-114	Resistor, Precision	4.0M, ± 1%, ½W	1-117802-4004
R-115	Resistor, Precision	2.5M, ± 1%, ½W	1-117802-2504
R-116	Resistor, Precision	2.5M, ± 1%, ½W	1-117802-2504
R-117	Resistor, Precision	4.0M, ± 1%, ½W	1-117802-4004
R-118	Resistor, Composition	100K, ± 5%, ½W	5-115557-104
R-119	Resistor, Composition	3.6K, ± 5%, ½W	5-115557-362
R-120	Resistor, Composition	3.6K, ± 5%, ½W	5-115557-362
R-121	Resistor, Composition	100K, ± 5%, ½W	5-115557-104
R-122	Resistor, Precision	39K, ± 1%, ½W	1-117802-3902
R-123	Resistor, Precision	1.1M, ± 1%, ½W	1-117802-1104
R-124	Resistor, Precision	390K, ± 1%, ½W	1-117802-3903
R-125	Resistor, Precision	390K, ± 1%, ½W	1-117802-3903
R-126	Resistor, Precision	1.1M, ± 1%, ½W	1-117802-1104
R-127	Resistor, Precision	470K, ± 1%, ½W	1-117802-4703
R-128	Resistor, Composition	100K, ± 5%, ½W	5-115557-104
R-129	Resistor, Composition	100K, ± 5%, ½W	5-115557-104
R-130	Resistor, Composition	27K, ± 5%, ½W	5-115557-273
R-131	Resistor, Precision	1.72M, ± 1%, ½W	1-117802-1724
R-132	Resistor, Precision	470K, ± 1%, ½W	1-117802-4703
R-133	Resistor, Precision	470K, ± 1%, ½W	1-117802-4703
R-134	Resistor, Precision	1.72M, ± 1%, ½W	1-117802-1724
R-135	Resistor, Ballast		119373
R-137	Resistor, Composition	1.1K, ± 5%, 2W	5-115559-112
R-138	Resistor, Precision	1.0M, ± 1%, ½W	1-117801-1004
R-139	Resistor, Precision	1.0M, ± 1%, ½W	1-117801-1004
R-140	Resistor, Precision	2.2M, ± 1%, ½W	1-117801-2204
R-141	Resistor, Precision	2.2M, ± 1%, ½W	1-117801-2204
R-142	Resistor, Variable	3M	227493
R-143	Resistor, Precision	2.2M, ± 1%, ½W	1-117801-2204
R-144	Resistor, Precision	2.2M, ± 1%, ½W	1-117801-2204
R-145	Resistor, Precision	5.4M, ± 1%, ½W	1-117802-5404
R-146	Resistor, Precision	5.4M, ± 1%, ½W	1-117802-5404
R-147	Resistor, Composition	68 ohms, ± 5%, 1W	5-115558-680
R-148	Resistor, Composition	68 ohms, ± 5%, 1W	5-115558-680

PARTS LIST (Cont'd)

SYMBOL	DESCRIPTION	VALUE	BRUSH PART NO.
R-149	Resistor, Composition	100 ohms, ± 5%, ½W	5-115557-101
R-150	Resistor, Precision	1.0M, ± 1%, ½W	1-117802-1004
R-151	Resistor, Precision	5.0M, ± 1%, ½W	1-117802-5004
R-152	Resistor, Precision	5.0M, ± 1%, ½W	1-117802-5004
R-153	Resistor, Precision	1.0M, ± 1%, ½W	1-117802-1004
R-154	Resistor, Precision	350K, ± 1%, ½W	1-117802-3503
R-155	Resistor, Variable	100K	19-211473-104
R-156	Resistor, Precision	150K, ± 1%, ½W	1-117802-1503
R-157	Resistor, Composition	220K, ± 5%, ½W	5-115557-224
R-158	Resistor, Composition	10K, ± 5%, 2W	5-115559-103
R-159	Resistor, Variable	1.0M	19-211473-105
R-160	Resistor, Composition	330K, ± 5%, ½W	5-115557-334
R-161	Resistor, Composition	220K, ± 5%, ½W	5-115557-224
R-162	Resistor, Precision	27K, ± 1%, 1W	1-117803-2702
R-163	Resistor, Precision	2.2K, ± 1%, ½W	1-117802-2201
R-164	Resistor, Precision	2.2K, ± 1%, ½W	1-117802-2201
R-165	Resistor, Precision	18K, ± 1%, 1W	1-117803-1802
R-166	Resistor, Composition	1 ohm, ± 10%, 2W	10-115556-1RO
S-1	Switch, Rotary		226491
S-2	Switch, Rotary		226394
S-3	Switch, Rotary		226428
S-4	Switch, Rotary		226659
S-5	Switch, Rotary		(Part of R-142)
S-6	Switch, Toggle	S.P.S.T.	121068
SA-1	Switch Assembly	(Includes R-1 thru R-9, R-56 thru R-59 and S-1)	426572-910
SA-2	Switch Assembly	(Includes C-13, R-102 and S-2)	426413-930
SA-3	Switch Assembly	(Includes R-82, R-83, R-84 thru R-99 and S-3)	426618-910
SA-4	Switch Assembly	(Includes R-101 and S-4)	326584-910
SA-5	Switch Assembly	(Includes C-18 thru C-24, R-138 thru R-146 and S-5)	427494-910
SR-1	Rectifier		227190
T-1	Transformer		121553
T-2	Transformer		124256
V-1	Tube, Electron	12AT7	109966
V-2	Tube, Electron	12AT7	125833
V-3	Tube, Electron	12AT7	125833
V-4	Tube, Electron	12AT7	125833
V-5	Tube, Electron	12AX7	125835
V-6	Tube, Electron	12AT7	125833
V-7	Tube, Electron	12AX7	125835*
V-8	Tube, Electron	12AT7	125833*
V-9	Tube, Electron	12AT7	125833*
V-10	Tube, Electron	5687	122828
V-11	Tube, Electron	5687	122828
V-12	Tube, Electron	6BW4	126997
V-13	Tube, Electron	6080	115687
V-14	Tube, Electron	5751	119028
V-15	Tube, Electron	6626	127658
WB-1	Board, Printed Wiring, Less Tubes		327202-910

*Replace 12AX7 only with 5751, and replace 12AT7 only with 12AT7WA. 12AX7 or 12AT7 Telefunken, Amperex, or Mullard tubes may also be used.

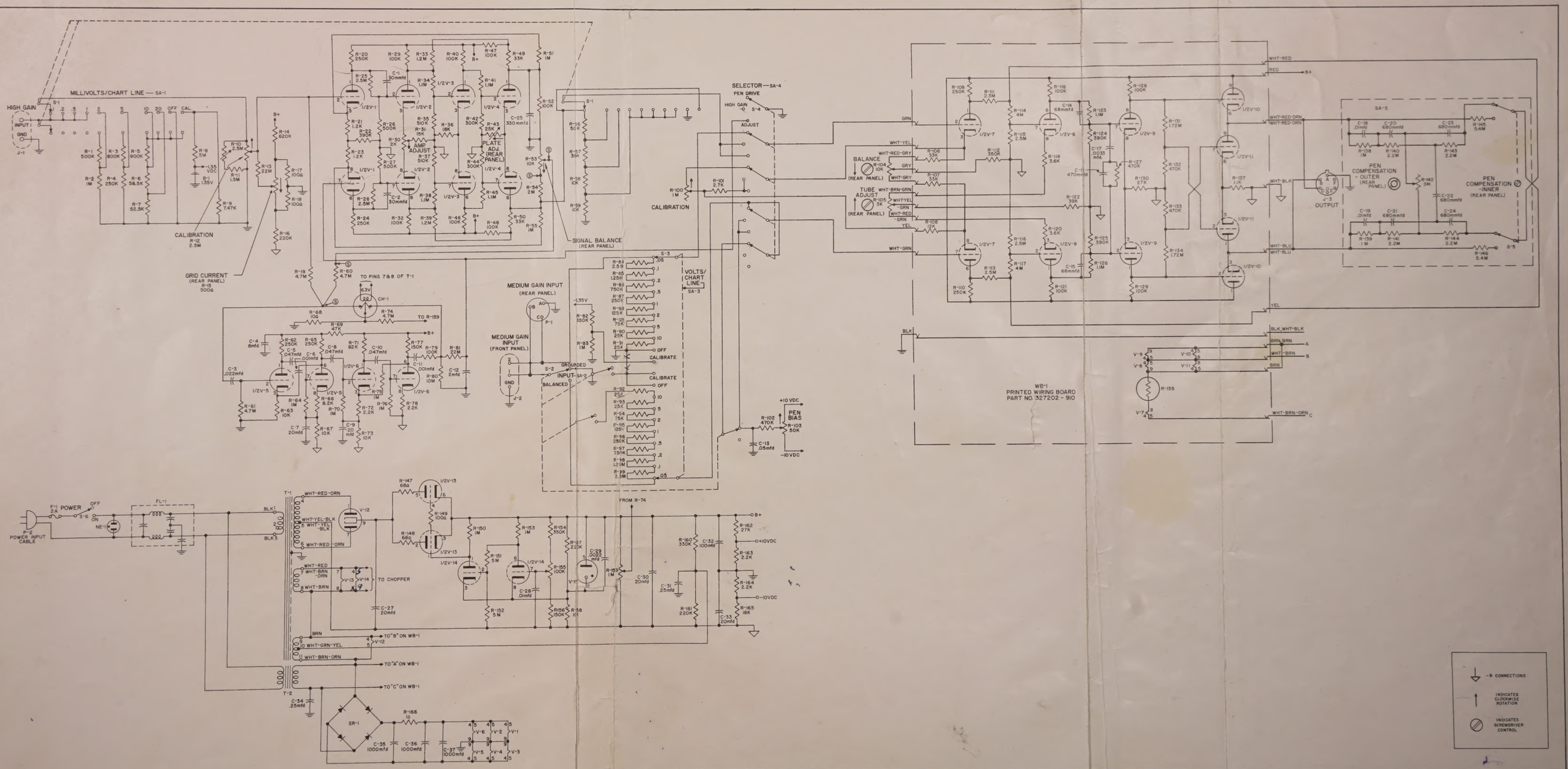
TUBE SOCKET PIN VOLTAGES

1. Voltages should be measured under the following conditions:
   a. High gain CALIBRATION control set for calibrated gain.
   b. MILLIVOLTS/CHART LINE switch in "off" position.
   c. SELECTOR switch set in "pen drive" position.
   d. Pen drive CALIBRATION control in full counterclockwise position.
   e. A 1500 ohm resistor connected across output terminals (pins "B" and "C" of output connector).
   f. Voltage across output resistor adjusted to zero (0 volts) by means of the PEN BIAS control.
2. All d.c. voltages should be measured with d.c. voltmeter with a minimum of ten (10) megohms input impedance.
3. All a.c. voltages should be measured with an accurate RMS a.c. voltmeter (20,000 ohms per volt or higher).
4. The +B voltage should be adjusted to 235 volts as described in the Operating Instructions under "Tube Replacement" (Section V—Maintenance).
5. All measurements should be made from the tube pin to −B (⏚) point, except where otherwise noted.
6. Variations in observed voltage readings from tabulated values do not necessarily indicate improper operation unless deviations exceed 10%.

TUBE No.	TYPE	PIN NUMBER								
		1	2	3	4	5	6	7	8	9
V-1	12AY7	185	94	96	Note 1		185	94	96	—
V-2	12AT7	122	Note 2	32	Note 1		122	—	32	—
V-3	12AT7	117	Note 2	40	Note 1		117	—	40	—
V-4	12AT7	90	Note 2	25	Note 1		90	—	25	—
V-5	5751	178	94	95	Note 1		148	3.0	5.0	—
V-6	12AT7	150	11	14	Note 1		100	0	2.0	—
V-7	12AX7	198	97	98	Note 3		198	97	98	—
V-8	12AT7	153	Note 2	58	Note 3		153	—	58	—
V-9	12AT7	150	Note 2	42	Note 3		150	—	42	—
V-10	5687	235	150	152	Note 4		150	152	—	235
V-11	5687	152	32	36	Note 4		36	32	—	152
V-12	6BW4	—	—	—	—	—	—	—	—	315
V-13	6080	—	—	235	—	—	235	Note 5		—
V-14	5751	Note 2		88	Note 3		Note 2		88	—
V-15	6626	—	—	88	—	235	—	—	—	—

NOTES:

1. 5.7 to 6.7 volts d.c. measured from pins 4 and 5 to pin 9.
2. Do not measure.
3. 6.3 volts a.c. measured from pins 4 and 5 to pin 9.
4. 6.3 volts a.c. measured from pins 4 and 5 to pin 8.
5. 6.3 volts a.c. measured from pin 7 to pin 8.


MILLIVOLTS/CHART LINE — SA-1
HIGH GAIN
INPUT
GND
CALIBRATION
GRID CURRENT
(REAR PANEL)
AMP ADJUST
PLATE ADJ (REAR PANEL)
SIGNAL BALANCE
(REAR PANEL)
SELECTOR — SA-4
PEN DRIVE
HIGH GAIN
ADJUST
CALIBRATION
BALANCE
(REAR PANEL)
TUBE ADJUST
(REAR PANEL)
MEDIUM GAIN INPUT
(REAR PANEL)
MEDIUM GAIN INPUT
(FRONT PANEL)
GROUNDED INPUT
BALANCED
VOLTS/CHART LINE
SA-3
CALIBRATE
OFF
PEN BIAS
+10 VDC
-10 VDC
TO PINS 7 & 8 OF T-1
TO R-159
FROM R-74
TO CHOPPER
PEN COMPENSATION - OUTER (REAR PANEL)
PEN COMPENSATION - INNER (REAR PANEL)
OUTPUT
WB-1
PRINTED WIRING BOARD
PART NO. 327202 - 910
F-1 POWER 2A
POWER INPUT CABLE
FL-1
T-1
T-2
SR-1
TO "B" ON WB-1
TO "A" ON WB-1
TO "C" ON WB-1
-B CONNECTIONS
INDICATES CLOCKWISE ROTATION
INDICATES SCREWDRIVER CONTROL

brush INSTRUMENTS

DIVISION OF

3405 PERKINS AVENUE CLEVITE CORPORATION CLEVELAND 14, OHIO

MP MASTER

MA30150